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Increasing Coal Mine Efficiency

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Washington, D. C.

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Increasing Coal Mine Efficiency—I

BY CHARLES E. STUART

United States Fuel Administration, Washington, D. C.

SYNOPSIS — *The first of a series of articles upon the subject of mine efficiency. Many operators and "practical" coal men do not yet realize that the power generation and distribution system of the fair-sized mine offers problems more complicated and intricate than exist in the ordinary town of 25,000 inhabitants.*

Introduction

IN ANY present-day consideration of coal-mine operation having in view increased coal production and operating efficiency, certain war factors must constantly be borne in mind. No study of the subject can be properly made without due allowance for existing war conditions, such as decreasing availability of required machinery; increased delay in obtaining factory repairs or repair parts; increasing load on central stations already frequently overtaxed; and decreasing man power incident to the requirements of the army and as a result of the tempting offers of other classes of war industry.

There is urgent demand for every pound of steel that can be produced. This is needed for the construction of ships, and for the manufacture of shells and other war material. Furthermore, the man with the skill to turn the axle of a mine locomotive can likewise turn an urgently needed shell; in a word, we are short of both skilled labor and raw material for imperative war requirements. Nevertheless, and in spite of these facts as well as because of them, we must increase the production of coal.

This series of articles will not be technical. An operator who regards himself as qualified to purchase a fan motor need not hesitate to study it because of the introduction of curves and other descriptive technical data. The operator capable of specifying and purchasing such a motor will recognize the information as elementary. He will also agree that the facts presented are logical, and they may perhaps recall considerations to which he has at odd times given some casual thought, or difficulties which he has definitely attempted to solve.

The fact that electrical and mechanical engineering skill has become as important a factor in the efficient management of mining properties as civil engineering ability, is today appreciated only by some of the larger and better organized operating companies.

Fig. 1 summarizes the results of a number of comparative analyses. The physical handicaps of the properties have a bearing on the extremes indicated, but

these considerations have, relatively speaking, only a small influence. The following report of power consumed and tonnage output is illustrative:

15-Min. Demand, Kw.	Consumption, Kw.-Hr.	Tonnage Output	Kw.-Hr. per Ton
Operation No. 1			
June 518	90,700	35,000	2.7
July 547	101,600	36,400	2.8
Operation No. 2			
June 374	112,100	60,599	1.9
July 412	123,400	60,946	2.0

Mine No. 1 consumes 40 per cent. more power and has 30 per cent. higher power demand. There is some difference in the operating conditions, but nothing that would cause such a wide variation of output to demand as that cited above.

The average town of 25,000 population contains a pumping plant, which takes its water from a single source by a single lift. The municipality contains a well-regulated trolley system. There may be several factories containing more or less complicated systems of electrical drive, and in each and every instance there is maintained a well-organized engineering force headed by a capable electrical or mechanical engineer, or an engineer manager.

The mine with a capacity of 1000 tons a day contains a generating or converting plant, the load upon which corresponds both in diversity and complexity to the combined requirements enumerated in the case of the town of 25,000. The pumping system of

the mine is invariably more complicated. If the miner is not properly served by the haulage system, he becomes idle through a greater or less period of time.

The subject of mine ventilation considered in relation to power demand and consumption is in itself an art to which the town offers no parallel. Extremely few factories, for instance, contain motor drives whose needs in the way of skilled attention compare with the requirements of a tippie designed to prepare coal properly for coking and for the market. The lighting requirements of the average mine camp are identical to those of the small town, provided the miners' homes are to receive reasonably good service and the mine itself is to be properly lighted.

In many instances a mine operator does not appreciate the complexity or possible efficiency of his expensive equipment, and is entirely satisfied with an electrician who can keep things going. Frequently, such electricians are capable of serious efficiency work and would gladly undertake it if requested or encouraged to do so and furnished with the necessary assistance. Such an attitude on the mine operator's part is distinctly shortsighted and results in loss of greatly needed coal production, both to the mining company and to the country.

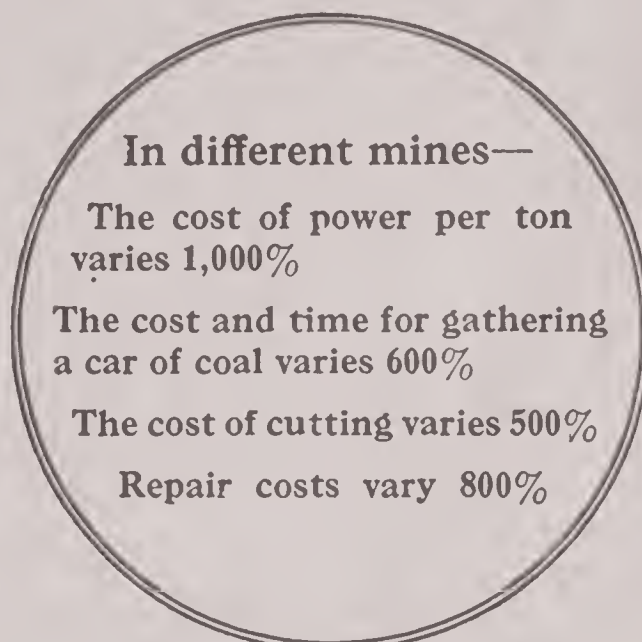


FIG. 1. COMPARATIVE ANALYSES SUMMARIZED

There is another phase of equal importance to the operator from a personal viewpoint—namely, the relationship of investigation and improvement recommended herein to cost and profit. Every recommendation made, if carried out, will save money; or, conversely, will make money for the mine operator. It should be remembered also that no suggestion is made in this series of articles whose value has not been fully demonstrated in practice. These suggestions are not impractical and will only

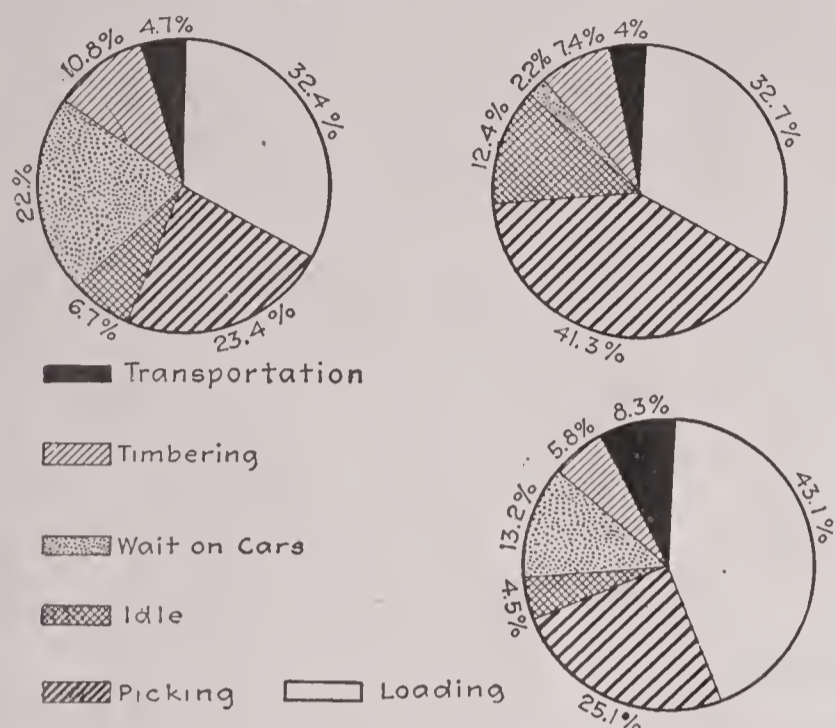


FIG. 2. COMPARATIVE PERFORMANCE OF MINERS IN THREE MINES

appear so to the superintendent or owner who is unable to grasp their significance, or who is unwilling to give the small amount of time necessary to digest the recommendations here made and put forth the subsequent effort that may be requisite in order to carry them out.

To repeat, I am endeavoring to bring to bear a few simple analyses to show that the mine operator with the help at hand is in position to go a great deal farther today than he is now going to meet the demand for conservation in its broad economic sense.

None of the considerations and conditions enumerated in the foregoing should be overlooked in considering the following factors in mine operation, which will be covered in this series of articles: (I) A comparative analysis of a miner's working day. (II) An analysis of the performance of mine locomotives. (III) An analysis of the performance of cutting machines. (IV) The power demand and consumption of mine fans. (V) An analysis of power demand and consumption of mines in relationship to capacity and production. (VI) An analysis of mine power conditions in relationship to production. (VII) A consideration of track conditions in relationship to production. (VIII) The condition of the generating plant. (IX) The relative output of electrified vs. unelectrified mines. (X) Considerations in the case of a shortage of central station capacity. (XI) A coal mine efficiently electrified using purchased power.

I—Comparative Analysis of a Miner's Working Day

Fig. 2 shows the comparative performance of miners in three different mines, two of which are electrified. To arrive at these summaries, a careful analysis was made not only of the actual employment of time by the miner, but also in order to locate and isolate all ele-

ments tending to delay him. It is the rule to blame the miner for a small day's production, but we rarely hear of the superintendent or foreman taking unto himself criticism for failure to keep the miner properly supplied with cars.

The showing in Fig. 2 is by no means a poor one, or below the average. On the contrary, the group of mines where the observations were made are supposed to be among the most efficiently operated in the country; and

TABLE I. AVERAGE PERFORMANCE OF EQUIPMENT AND MINERS

Hoist:			Gatherers:		
	Minutes	Per Cent.		Minutes	Per Cent.
Hoisting cars.....	231	51.2	Hauling.....	286	49.7
Hoisting supplies....	125	22.3	Running light.....	81	14.1
Waiting for loads....	123	22.0	Waiting on loads....	89	15.5
Wrecks.....	60	10.8	Waiting on empties..	75	13.0
Idle.....	21	3.7	Waiting on drivers..	...	...
			Wrecks.....	28	4.9
Total.....	560	100.0	Idle.....	16	2.8
Haulage Motors:			Total.....	575	100.0
Hauling.....	284	49.3	Miners—Average of 6 Men		
Running light.....	39	6.8	Loading.....	217	41.9
Waiting on loads....	73	12.6	Picking.....	141	27.2
Waiting on empties..	10	2.0	Idle.....	53	10.2
Waiting on motors..	...	...	Waiting on cars....	60	11.5
Wrecks.....	164	28.2	Timbering.....	25	4.8
Supplies.....	6	1.1	Transportation.....	23	4.4
Total.....	576	100.0	Total.....	519	100.0

furthermore, their output of coal per miner is a record output. Table I gives several average performances of equipment and miners.

Fig. 4 is a graphic analysis of daily performance showing how the summary in Fig. 2 and the comparative analysis in the table are obtained. We are particularly concerned with those elements of delay which bring about the "wait on cars." Such delays may be classified under the heads of "avoidable" and "unavoidable." Unavoidable delays are those such as occur in any system of transportation. For example, there will be delays incident to transfer of cars from one loco-

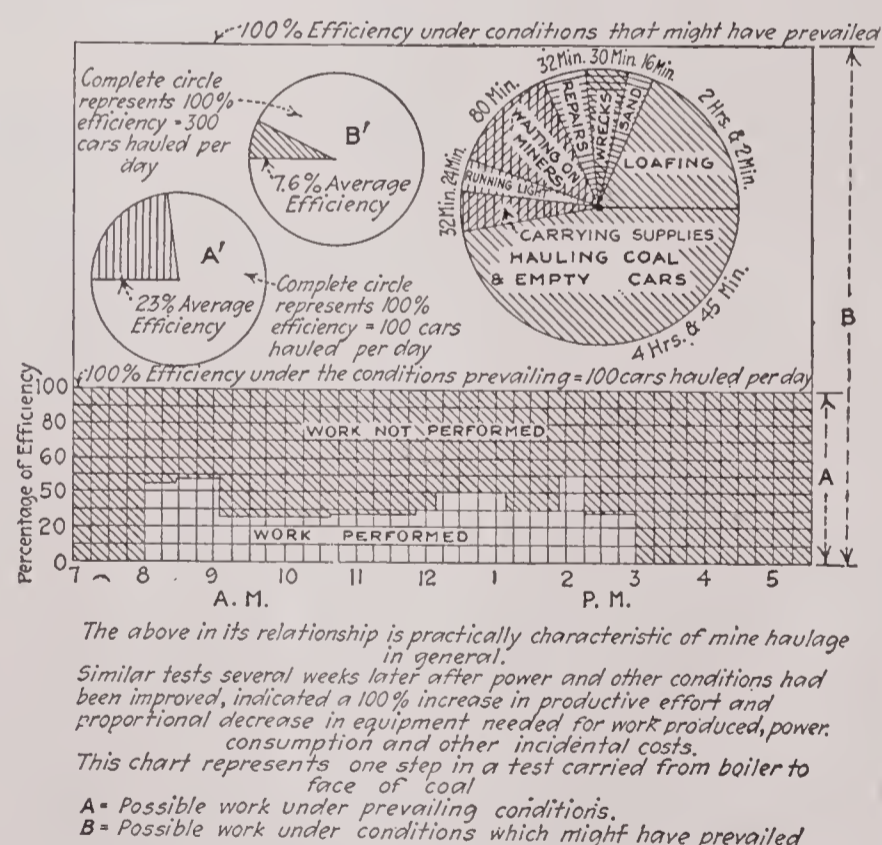


FIG. 3. GRAPHIC ANALYSIS OF DAILY PERFORMANCE OF LOCOMOTIVES

tive to another. Wrecks may occasionally be classified as unavoidable.

In a general way, avoidable delays as here considered are such as are occasioned by a section of the haulage system being congested or inadequate for the work. The chief causes which are responsible for the element of

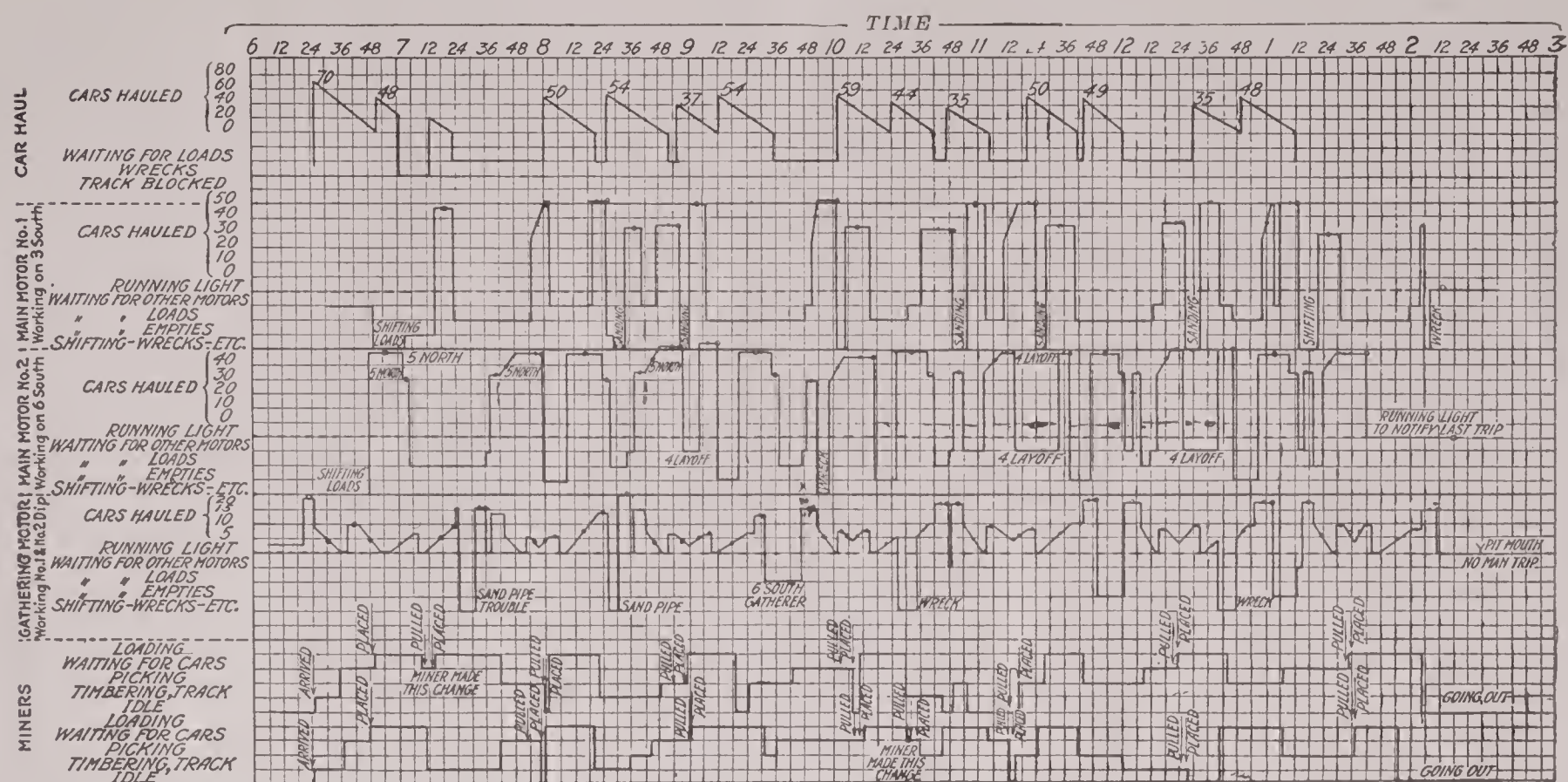


FIG. 4. COMPOSITE RECORD OF PERFORMANCE OF LOCOMOTIVES AND MINERS

time loss shown in Fig. 2, and which may be classified as avoidable, are as follows: (1) Handling supplies; (2) sanding motors at other points than where stops are regularly made; (3) insufficient capacity of loaded and empty partings; (4) poor signal system; (5) insufficient number of cars; (6) wrecks; (7) locomotive trouble due to lack of inspection; (8) delay due to failure to place car ready for miner on his arrival; (9) indifference of motormen; (10) bad management.

II—Analysis of Mine Locomotive Performance

The converse of the analysis of a miner's working time is indicated in Fig. 3. Here we have the composite record of the average performance of a number of gathering locomotives as taken in different mines. Prac-

tically speaking, the record is characteristic of mine haulage. One hour and 20 minutes out of the day is shown waiting on miners and 2 hours 2 minutes are spent in idleness or loafing.

I have observed many tests of mine locomotives with the object of developing such comparisons as the foregoing. I have never observed a single test—that is to say, a trial carried through the period of a day—that failed to show serious elements of time lost that could not be classed under the head of avoidable.

The elements of delay derived in Section I are also the basis of time wastage in the locomotive movement. In fact, as is readily appreciated, a delay which would prevent the prompt serving of a miner with cars would similarly as a rule reduce the efficiency of operation of

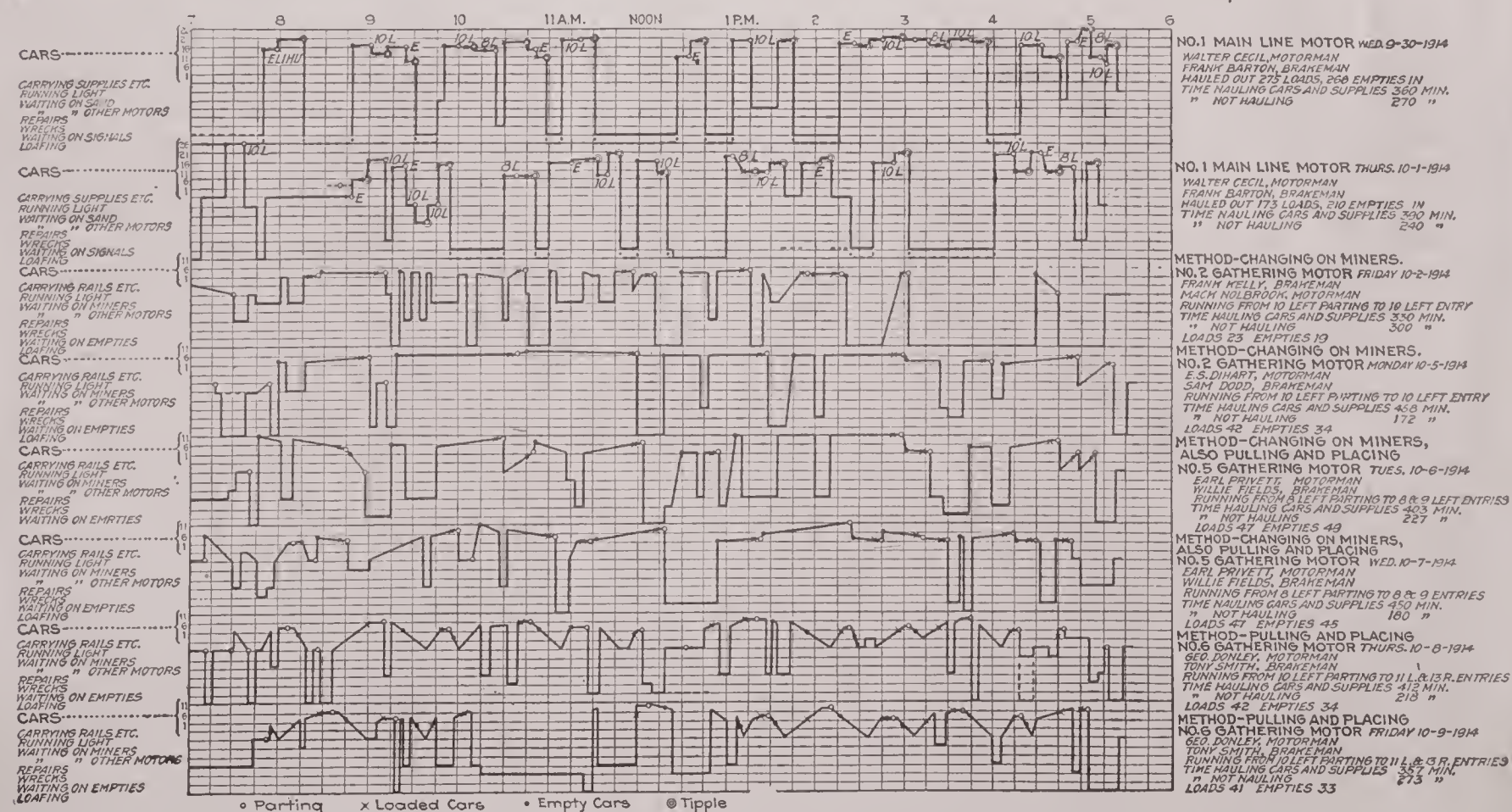


FIG. 5. CHART OF PERFORMANCE OF SEVERAL LOCOMOTIVES IN THE SAME MINE

the haulage system. There is also the factor of management which adjusts the movement of locomotive and cars to the requirements of the miner. Failure to properly make such adjustment will necessitate either the locomotive waiting on the miner or the miner waiting on the locomotive.

Fig. 5 is the chart of one day's work of several locomotives in the same mine. Such a chart can be easily developed for the entire haulage system so as to isolate the elements of avoidable time wastage. If such an analysis is properly prepared for and accurately conducted, it will usually be found that locomotives which were thought necessary can be done without. It will often be discovered that a mine overequipped from a haulage standpoint. I have observed increases of more than 100 per cent. in productive effort following carefully conducted examinations of this character.

A locomotive is usually regarded as necessarily subject to frequent breakdowns incident to controller trouble, bearing trouble and armature burnouts. When these troubles are too frequent, the manufacturer is blamed. Nevertheless the manufacturers who supply a considerable proportion of mine locomotives in use likewise supply approximately 100 per cent. of street-car motors, which are in nearly all respects similar in design to the mine motor.

A street-car motor is supposed to last about five years before it becomes necessary to rewind it. During that period it is expected to do 200,000 car-miles. Provided a mine motor is of proper capacity for its work, there is no reason why its lasting qualities measured in period of time should not be equal to that of the street-car motor. The mileage, of course, will not compare.

WHY MOTOR TROUBLE ON STREET CARS IS RARE

We all know how rare it is for a street car to stop on account of motor trouble. In spite of the number of cars in operation in a great city, a tie-up on account of trouble with a motor is a rare occurrence. The reason is that the rated voltage is supplied at all times and there is daily inspection.

I visited a number of mines in Germany some years ago in order to observe the mine machinery in use. On commenting upon a daily delay sheet that was kept, and the absurdly low repair cost as well as the small amount of time used in effecting repairs, I was advised that this was due to the daily inspection which all machinery underwent. The rule of the railways should be followed and the mine locomotive should be subjected to daily inspection by a competent man. The following

parts should be examined with particular care daily: First, controller segments should be filed and greased with vaseline. Second, every bearing should be oiled and packed. Third, brushes and commutators should be watched carefully. Fourth, the distance between armature and pole pieces should be gaged weekly. If these parts are kept under observation in the manner suggested, locomotive troubles will become nearly negligible and actual breakdown in the mine will become practically unknown.

A suggestion in connection with the operation of the haulage system, which on its face may appear radical, is what might be termed in a dispatcher system, corresponding to the system in use on all electric railways as well as railroads. We have reference to a man whose duty it would be to observe and systematize the movement of equipment in the mine and who would keep check on delays of the character recorded in Sections I and II. He should maintain a system of checks and charts which would throughout the day's work inform him as to the condition of the rooms and the relative location of cars, locomotives and machines. This man, if of the proper training, could also carry out or direct the tests and investigations recommended in the several sections. We have observed the partial adoption of this system in one or two cases, and the results have been gratifying. There is no question but that if the mines of the country would adopt such a system, and if competent men could be utilized for the work, exceedingly valuable results would follow in relationship both to cost and production.

There should be at the disposal of the mine officials or a dispatcher a comprehensive mine telephone system. A good telephone system is as necessary to efficient mine operation as it is to a trolley system or a railroad. It will increase production and reduce the cost. It is the opinion of coal properties in which telephone systems have been installed that these systems rapidly become essential to efficient handling of the mines.

Mines which have been equipped with telephone service, and these systems properly used, have shown marked increase in production through scheduling of main-line locomotives. The telephone tends to reduce the number of wrecks. It enables the mine foremen to keep in touch with each locomotive, making it possible for them to direct and control movements to advantage. We believe from observation of mines that have installed telephone systems that it is one of the best investments a mine operator can make. When properly installed, the maintenance is a small item.

Increasing Coal Mine Efficiency—II

BY CHARLES E. STUART
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SYNOPSIS—*In a general way, cutting machines are quite similar in their power requirements to locomotives. The proper means and speeds for driving mine fans as well as properly maintained air courses sometimes result in enormous economies in power. Fluctuating loads on the mine generating station or substation should be avoided as far as possible. This is often much more nearly possible than many operators believe.*

III—An Analysis of Performance of Cutting Machines

THE general considerations which govern the utilization of a mine locomotive, in order that maximum efficiency may be obtained, apply in a similar manner to the cutting machine. There are, broadly speaking, the same elements of avoidable and unavoidable loss of time. There is also the need of so developing the mine that the cutting machine can be used at its rated capacity. Bad power conditions and inefficient handling are factors to the same degree, as in the case of the locomotive, and there is the same loss in productive effort.

The ideal method of working a cutting machine is to give one machine a section containing sufficient places to enable the machine runners to cut each place every other day, letting the loaders clean up in the same manner. If this be done, the machine runners usually stay on one entry and go into the rooms consecutively instead of running all over the mine to cut a place here

and another there, thus consuming more time in tramming than in cutting.

In some of the large mines in Pennsylvania and Illinois these ideal cutting conditions are very nearly attained. In one case with which I am familiar, the

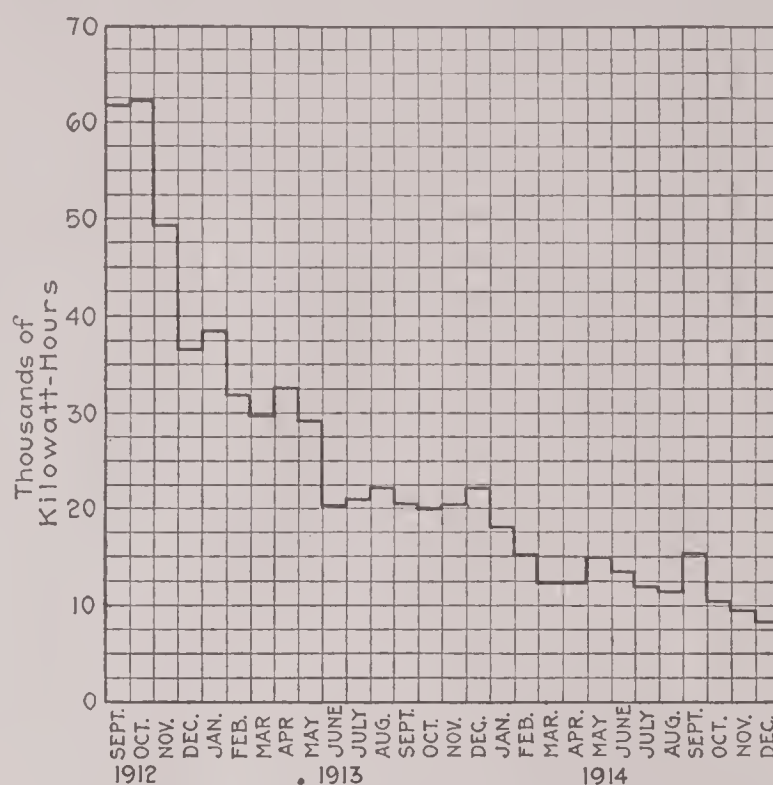


FIG. 6. RESULT OF IMPROVEMENTS IN VENTILATION ON POWER CONSUMED

depth of the undercut has been proportioned to the width of the room and the height of the coal, in order to give just enough coal for the loaders to clean up in one or two full days. This enables the maximum effort to be put forth by the loader and machine runner.

TABLE II. RECORD TAKEN THROUGH A PERIOD OF 31 DAYS, USING A SULLIVAN SHORTWALL CONTINUOUS CUTTER
September 3 to October 12, 1917

Date	Total Places	Rooms	Width, Ft.	Headings	Width Ft.	Narrow Places	Width, Ft.	Total Face, Ft.	Average Cut, Depth, In.	Total Hours Worked	Time Waiting for Places, Etc., Hr. & Min.	Actual Hours Work	Time per Place, Min.	Height of Coal, Ft.
Sept. 1														
3	5	2	24	3	14	2	14	70	84	10:00	6:40	3:20	40.0	5½
4	5	2	24	2	14	1	14	90	82	10:00	6:20	3:40	44.0	5½
6	9	2	24	3	14	4	14	146	81.2	10:45	6:10	5:35	37.2	5 to 6
8	2	2	12	..	..	..	..	24	83	4:15	3:30	0:45	22.1	5½
11	9	2	24	5	24	2	14	196	85	3:45	1:05	4:40	31.1	5½
12	9	3	28	4	14	2	14	168	84	6:45	1:45	5:00	33.3	5½
13	12	6	24	5	14	1	14	228	80	8:00	1:60	6:10	30.1	5½
14	12	7	25.6	4	14	1	14	250	84	10:00	3:50	6:10	30.1	5½
15	11	6	24	3	14	2	35	266	84	6:30	1:00	5:30	30.0	5½
17	10	10	25	..	..	..	..	250	83	6:20	1:05	5:15	31.0	5 to 6
18	8	4	31.5	4	14	..	..	182	81	8:00	3:00	5:00	37.4	5½
19	9	6	26.3	3	14	..	..	200	82.2	10:30	5:30	5:00	33.3	5 to 6
20	5	4	24	1	14	..	..	110	84	8:00	0:30	2:30	30.0	5½
21	15	8	24	7	14	..	..	290	84	7:45	0:45	7:00	28.0	5 to 6
23	9	8	24	1	14	..	..	206	85	5:45	0:45	5:00	33.3	5 to 6
24	10	7	24	3	14	..	..	210	83	5:00	1:00	4:00	24.0	5 to 6
25	12	11	31.5	1	14	..	..	360	83	8:00	1:05	6:55	34.7	5 to 6
26	14	4	24	5	14	5	20.8	270	81	7:30	1:00	6:30	27.12	5 to 6
27	9	7	22.5	2	14	..	..	186	86	10:50	5:35	5:15	35.0	5 to 6
28	6	2	29	3	14	1	16	116	80	10:00	7:35	2:25	24.1	5 to 6
29	13	10	24	1	14	2	14	282	84	6:30	0:45	5:45	26.7	5 to 6
Oct. 1	19	13	24	..	..	6	14	395	83	9:00	1:05	7:35	25.0	5 to 6
2	10	7	24	2	14	1	14	207	82	7:00	2:30	4:30	25.0	5 to 6
3	18	11	24	7	14	1	14	376	84	9:30	1:10	8:20	27.14	5 to 6
4	7	8	24	1	14	1	16	150	84	3:45	0:40	3:05	35.0	5 to 6
5	12	8	24	2	14	2	14	248	81	6:35	0:55	5:40	28.4	5 to 6
6	5	3	24	2	14	..	..	100	86	4:30	1:30	3:00	36.0	5 to 6
8	21	9	24	11	14	1	14	284	84	10:00	1:25	8:35	24.11	5 to 6
9	13	9	15.8	2	14	2	14	198	83	7:30	0:35	6:35	30.5	5 to 6
10	13	6	24	4	14	3	14	242	85	8:00	1:45	6:15	28.11	5 to 6
11	5	3	24	2	14	..	..	100	84	4:00	1:30	2:30	30.0	5 to 6
31	317	184	24.2	93	14.3	40	15.6	6,391	83.26	231:00	73:10	157.50	29 87 Min.	66in.

Table II shows a record taken through a period of 31 days, using the Sullivan shortwall continuous cutter. During this time 317 places were cut, or an average of 10.22 places per day. Column 12, headed "Time Lost Waiting for Places," shows that 73 hours 10 minutes were lost. The runner's report shows that probably 75 per cent. of this delay could have been avoided.

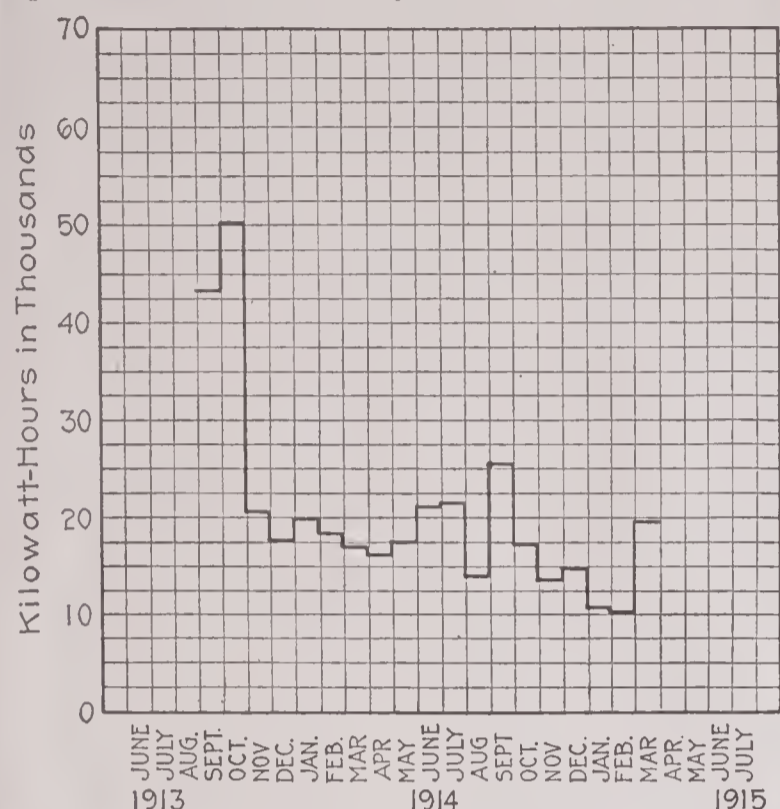


FIG. 7. POWER CONSUMPTION OF A MINE FAN

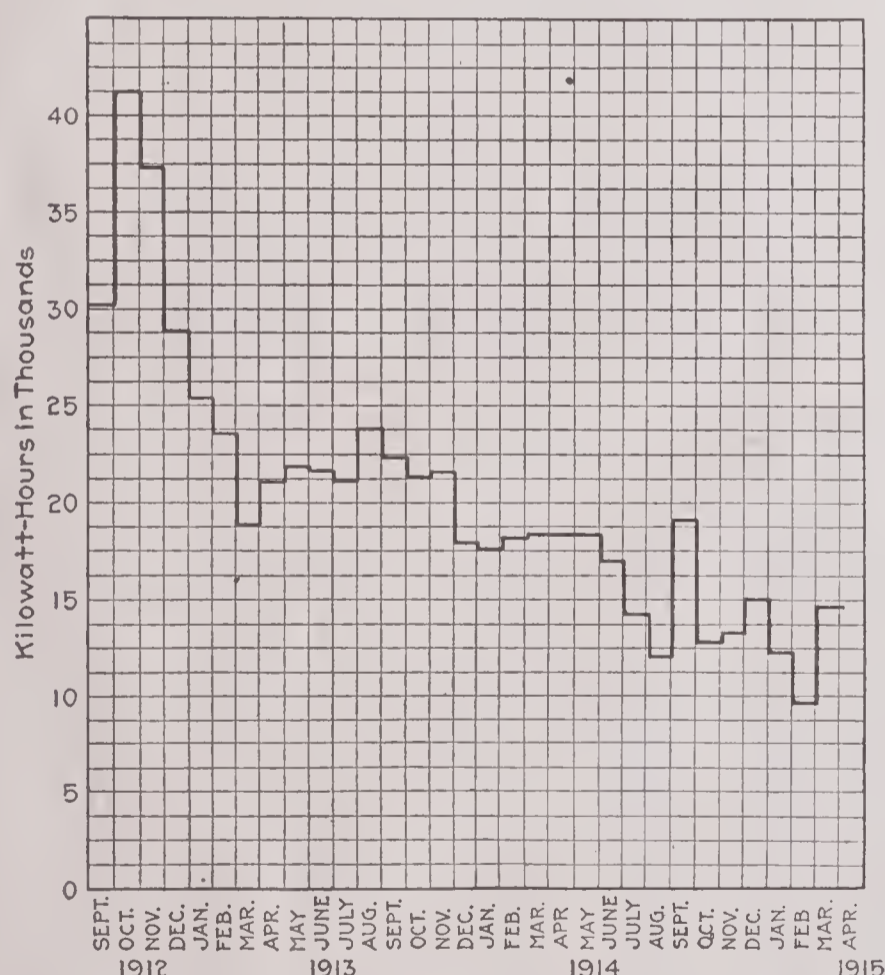


FIG. 8. POWER CONSUMPTION OF A MINE FAN, SHOWING RESULT OF VENTILATION IMPROVEMENTS

These delays were designated as arising from such causes as "blocked by motor," "no more places cleaned up," "off the track," etc. Since the average time consumed in cutting a place was a little less than 30 minutes, it is probable that 100 additional places could have been cut if these delays had not occurred, making a total of 417 places, or an average of about 13 places per day. The average noted in Table II is above the

usual. There are cases where runners have cut from 17 to 22 places in 10 hours, these being, however, record runs.

Table III represents tests of power consumption of Sullivan room-and-pillar machines, with a 6-ft. 6-in. and 10-ft. 4-in. cutter-bars. It also gives the comparative economies of machines. There is no information contained in these tables which would not be of interest and value as determined at every property using a cutting machine. These tests and supplementary observations develop the following facts: The first cost of the machines is practically the same. Repairs on the longer bar machines are less than those on the shorter machines; they are heavier throughout and have fewer parts relatively. Experienced men can cut as many

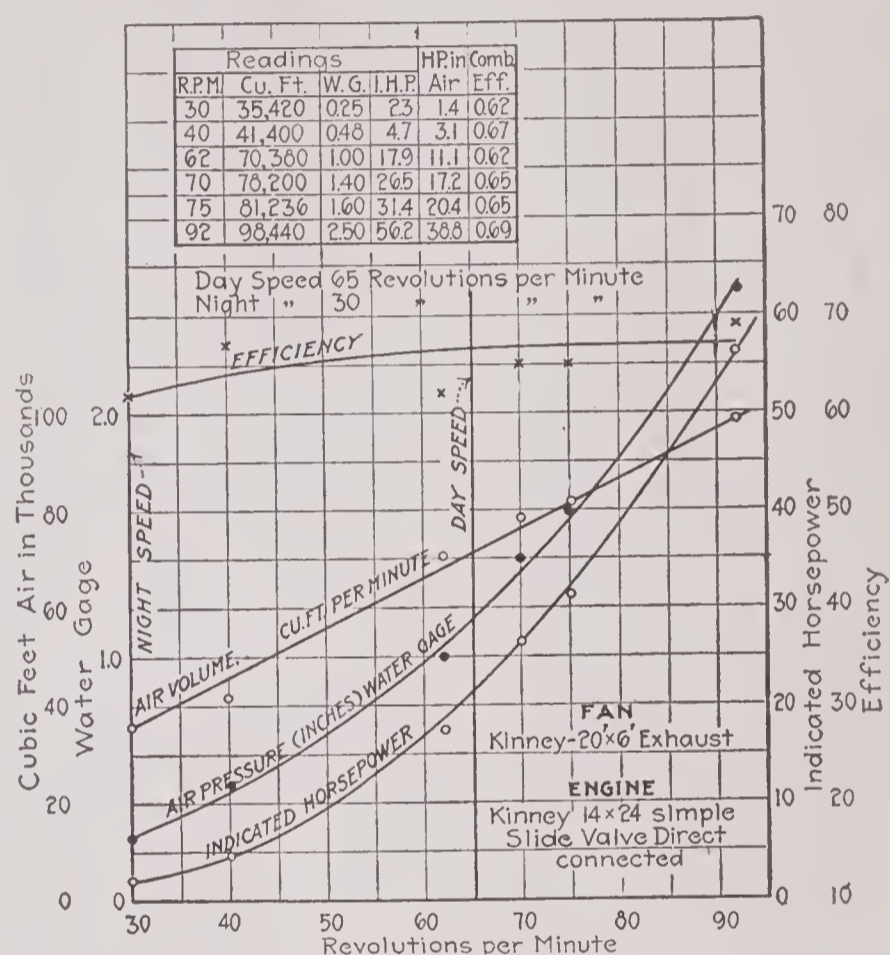


FIG. 9. POWER REQUIRED BY STEAM-DRIVEN MINE FAN

places with the long bar machines as with the short bar machines if voltage is maintained. Loaders after the long bar machines use less powder per ton of coal, as the same total amount of powder is used per place.

IV—Power Demand and Consumption of Mine Fans

Figs. 6, 7 and 8 show the results of alterations made with the object of reducing power consumption and power demand of mine fans. These alterations were preceded by investigations and tests which developed the following facts: (1) The fans were handling an amount of air in excess of the requirements of the mine; (2) large proportions of this air failed to reach the working faces, due to leakage, defective stoppings, brattices and similar reasons; (3) the air pressure, as shown by the water gage, was unduly high, owing to the air current being carried in too few splits.

These conditions were corrected by carrying to the faces the full amount of air required for good ventilation and by reducing the speed of the air current. Stoppings were repaired, and stone was substituted for timber in their construction. The speed of the air

TABLE III. TESTS OF POWER CONSUMPTION OF SULLIVAN ROOM-AND-PILLAR MACHINE WITH 6 FT. 6 IN., AND 10 FT. 4IN. CUTTER-BARS AND COMPARATIVE ECONOMY OF MACHINES
Power Consumption of 6 ft. 6 in. Sullivan Mining Machine—No. 10 Mine—No. 3 Seam

Watt Hours per Square Foot Undercut										Trolleying		Total Aver. Power		Dimensions		Height of Coal, Ft.										
1913 Date	No. Pies. Cut	Unloading		Placing		Sumping		Cutting		Pulling Out		Loading		Power in Place			Aver. Power	Sq. Ft. Undercut	Per Place	Sq. Ft. Undercut	Depth of Cut	Width of Cut	Sq. Ft. Undercut			
		Min.	Max.	Min.	Aver.	Min.	Max.	Min.	Aver.	Min.	Max.	Min.	Aver.	Min.	Max.	Min.								Max.		
7/7	6	0.1515	0.555	0.255	1.53	5.13	3.195	21.37	16.97	0.77	1.667	1.042	0.357	1.39	0.83	19.4	29.6	24.8	1.778	167	794	2,402	25.6	15.6	6.0	94
7/8	7	0.1515	0.512	0.344	1.515	5.0	2.4	11.07	17.41	0.53	1.791	0.875	0.303	2.12	0.74	14.78	25.42	19.1	1.447	139	665	1,969	20.5	16.3	5.3	96
Total, Aver.,	13	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
								

Fan, 14' Jeffery
Exhausting
Engine, 17"x18"
Chandler
and Taylor

READINGS					
SPEED- R.P.M.	WATER GAGE	CU. FT. AIR PER MIN	I.H.P.	H.P. IN AIR	COMB. EFF. %
60	0.5	71,500	12.8	56	0.44
80	0.9	104,000	22.8	14.7	0.65
90	1.2	*117,500	28.8	*19.3	*0.67
100	1.4	*132,500	36.8	*25.9	*0.71
104	1.5	137,000	45.0	32.4	0.72

* Estimated from Curve

Normal Operation,
Day-10 Hrs. at
95 R.P.M.
Night and Holidays-
8 Hrs. at 65 R.P.M.

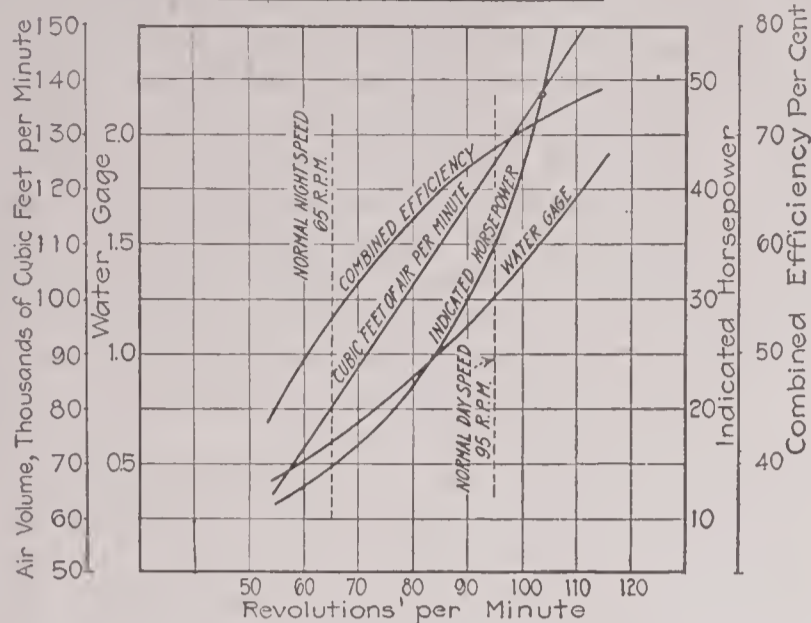


FIG. 10. CURVES OF A STEAM-DRIVEN MINE FAN

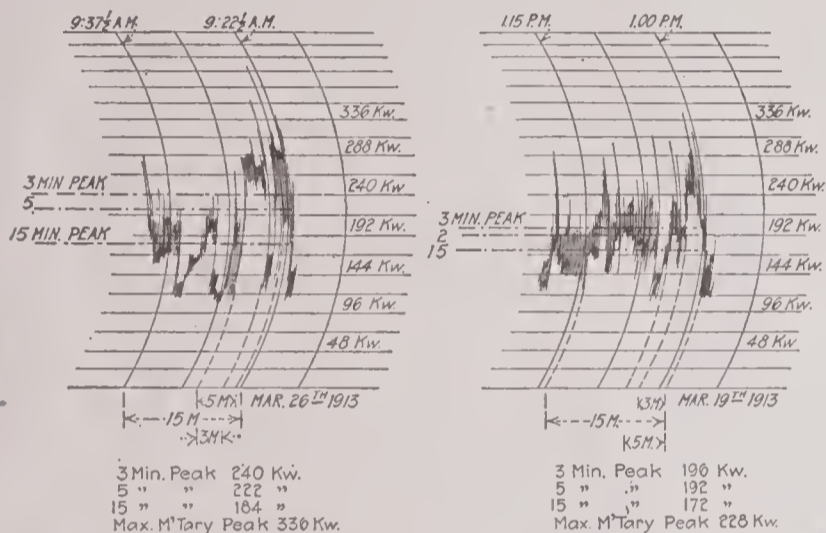


FIG. 11. DEMAND CURVES ON A 200-KW. PLANT

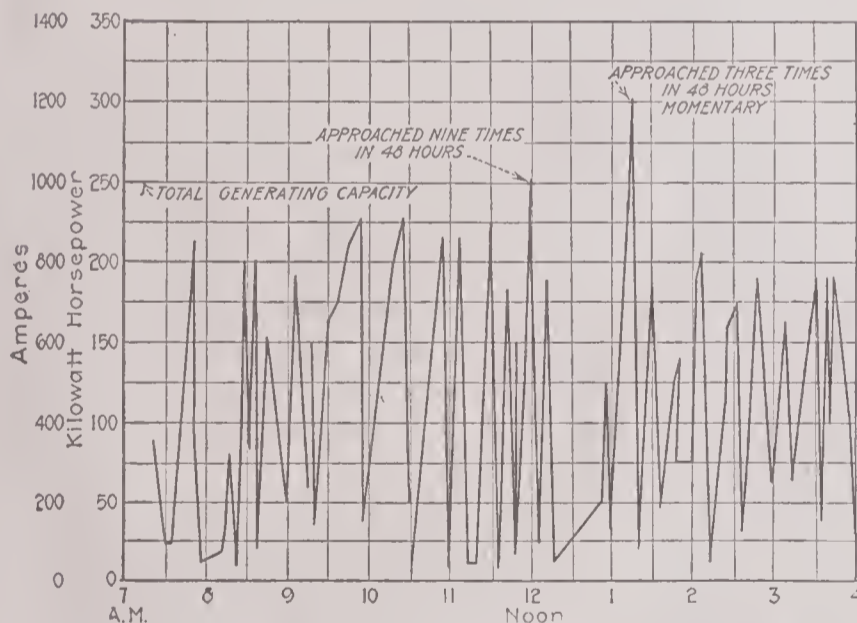


FIG. 12. ANALYSIS OF A MINE LOAD

loads up the station. Few mines are above criticism in this respect. With a large percentage of mines the load on the generating or converting station is largely composed of more or less avoidable demands.

Moreover, to an extent that is rarely appreciated, such conditions create a "bottle neck" to the entire haulage system. Thus a 10-ton mine locomotive on

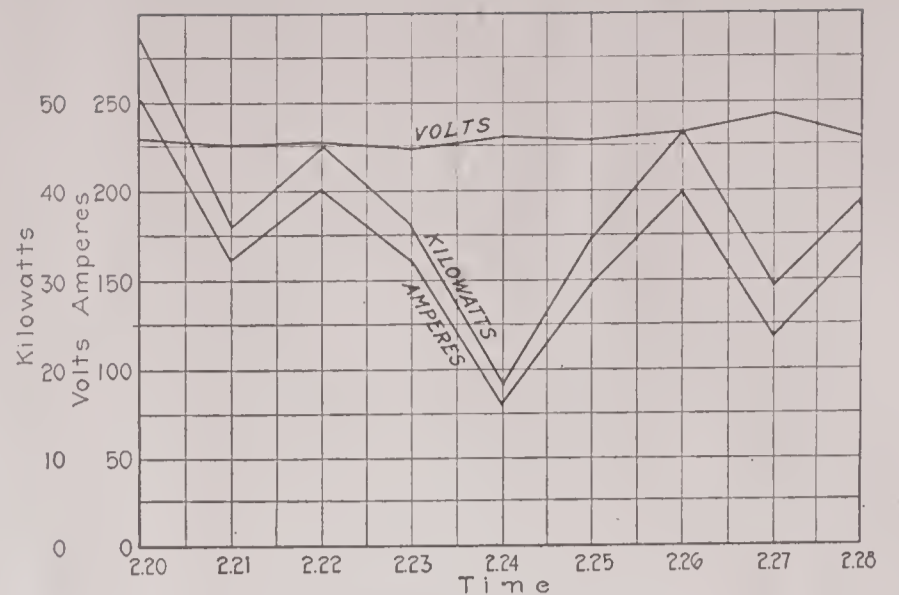


FIG. 13. POWER CONSUMED BY AN 80-HP. LOCOMOTIVE, PULLING 20 EMPTIES

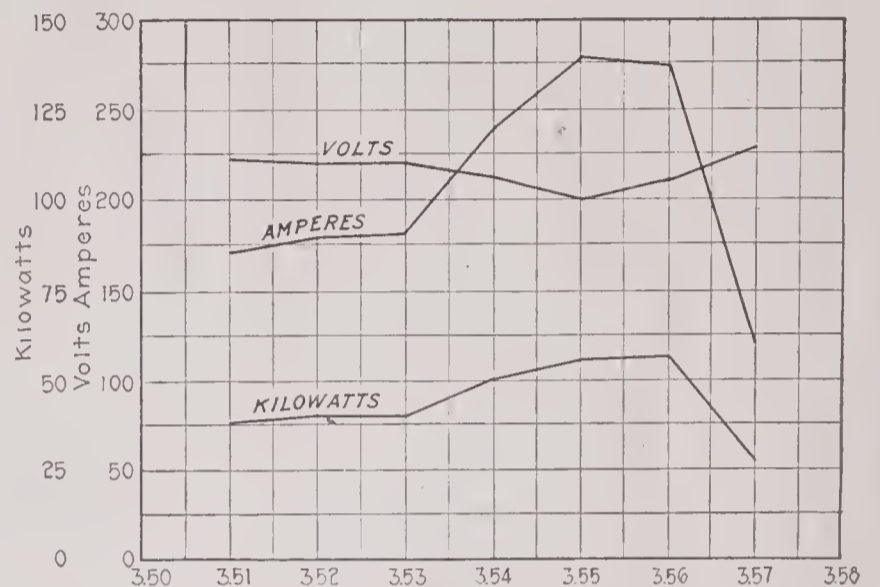


FIG. 14. POWER CONSUMED BY AN 80-HP. HOIST, PULLING 12 LOADED CARS

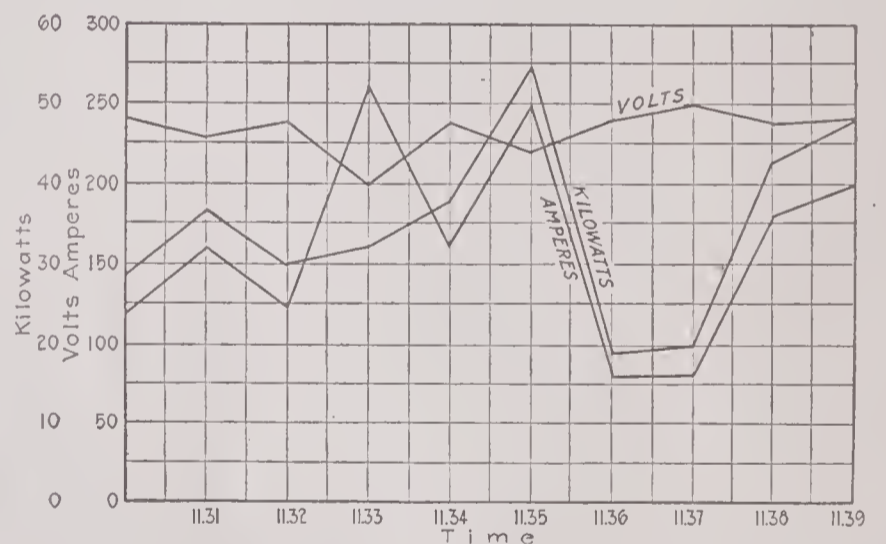


FIG. 15. POWER DEMAND OF TYPE B LOCOMOTIVE OF 80-HP., HAULING 6 LOADED CARS

level track should haul 31 loaded cars of 4 tons each. The same locomotive on a 6 per cent. grade will haul eight 4-ton cars, thus showing a decrease of 281 per cent.

It will be seen that the grades may be the determining factor in the number and weight of locomotives required, the capacity of the generating station or substation; also as to the weight of rails, the power demand and the power consumption.

Fig. 12 shows the analysis of a load as observed between the hours of 7 a.m. and 4 p.m. From the chart the plant seems to be as well loaded as is conservative. It was, however, desired to add to the load as shown a hoist demanding 150 kw. at full load, or

an additional 600 amp. In order to determine whether the generating plant could take care of such an additional demand, a test was run on those loads, which were the factors for consideration.

Figs. 13, 14, 15 and 16 show the demands of the locomotive and hoist on different dips. Adding the hoist load in this instance simply necessitated preventing the maximum demands of the locomotives occurring simultaneously. Where grades could not be reduced or avoided, there were two practical methods available to flatten the haulage demand; one, that of a simple signal-

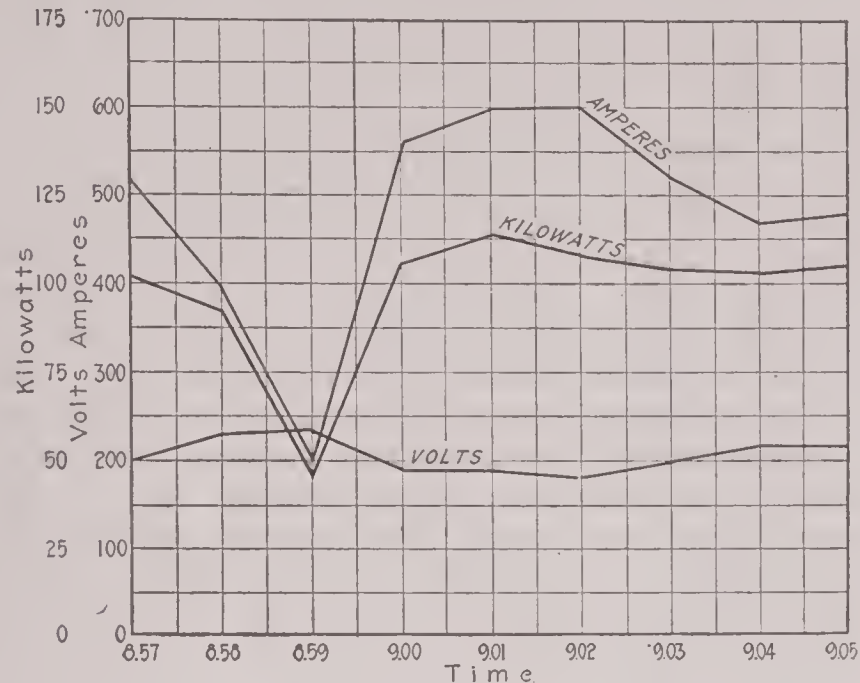


FIG. 16. POWER CONSUMED BY 2-F LOCOMOTIVES OF 200-HP., HAULING 14 CARS

ing device which would indicate trips on grade; the other roughly scheduling the main haulage locomotives.

The majority of mines on careful examination and test from an electrical and mechanical standpoint will develop the following facts: (1) By systematizing the load, a steam station or substation apparently overloaded with the breaker tripping many times a day, resulting in loss of speed and efficiency, can be operated in a normal manner. (2) Conversely, many stations apparently fully loaded can take on more cutting machines or locomotives without addition to either substation or steam station, as the case may be.

Table IV, showing a monthly analysis of power consumption, was made with the instruments belonging to the mine investigated. The cost of the instruments necessary to such an analysis is negligible compared with the savings which have resulted from their use.

It is characteristic of the mine as of the factory that

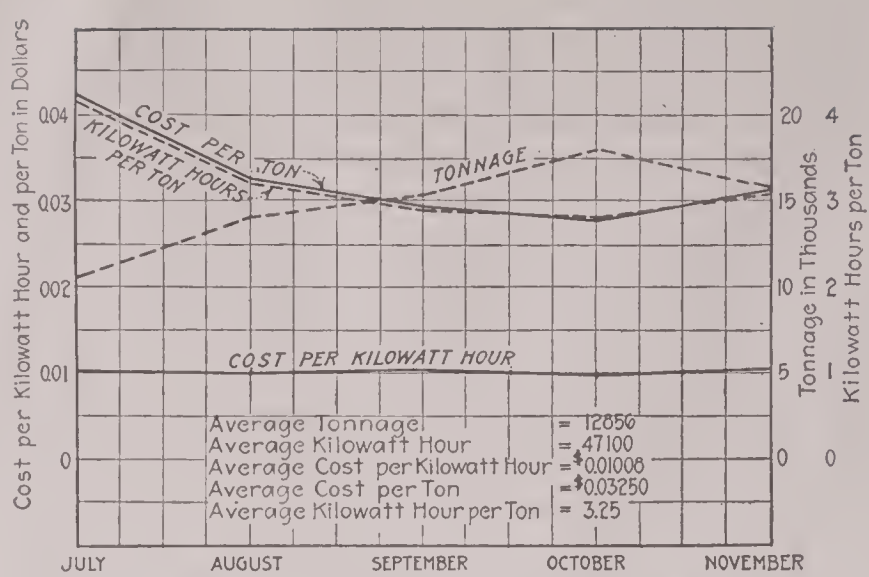


FIG. 17. OUTPUT, CONSUMPTION, COST PER TON AND PER KILOWATT-HOUR OVER 5 MONTHS

there is more or less idle machine operation. This is particularly true where a mine is equipped with more than one converting or generating set. It is, moreover, generally appreciated that machinery is operating at its highest efficiency when approximately fully loaded. While the characteristics of power demand in a mine make full load operation of most of the equipment out of the question, at the same time through analyses such as the foregoing, and through systematizing, the power consumption and demand of many mines have shown marked reduction. This in turn has been reflected to a valuable extent on the cost sheet.

There is a psychological aspect to this as in many other cases of economies produced and demonstrated.

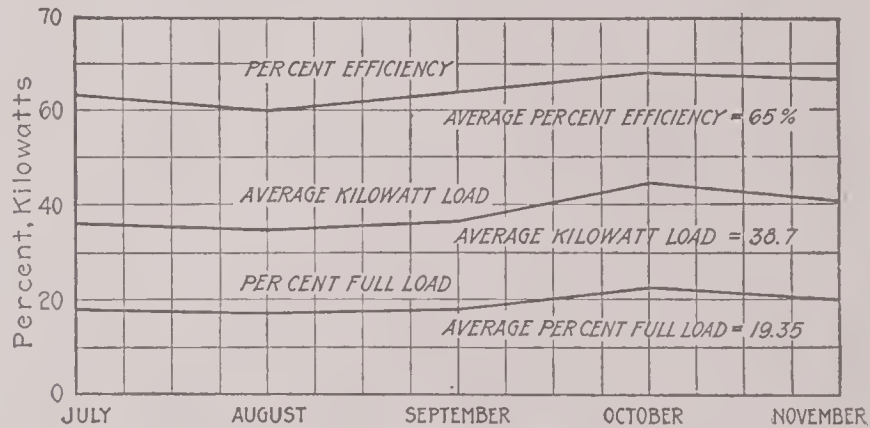


FIG. 18. RATIO OF AVERAGE CONSUMPTION TO FULL LOAD CAPACITY

An organization trained to give thought to such points will invariably give thought to other possibilities for reducing costs and for increasing the efficiency of operation.

Figs. 17, 18 and 19 develop graphically important facts

TABLE IV.—MONTHLY ANALYSIS OF POWER CONSUMPTION (Alternating Current Power Consumption, Kilowatt-Hours)															
	Town Light ing	Town Pump	Sub- station Light- ing	Shop Light- ing	Tipple Light- ing	Barn Light- ing	Shop- Power	Supply House	Rock Hoist	Car Haul	A.-C. Line Losses	Conver- sion Losses	M.G.Set Effi- ciency	D.-C. Meter	Total
July.....	2,225	528	31	10	..	..	260	..	530	290	250	14,906	63.0	25,570	44,600
August.....	1,925	1,548	21	17	..	..	280	..	610	280	250	16,499	60.0	24,670	46,100
September.....	2,400	.....	20	32	..	..	320	..	600	350	250	15,068	64.0	26,660	45,700
October.....	2,550	.....	5	27	12	2	290	..	830	470	200	13,694	70.5	32,620	50,700
November.....	2,750	.....	8	60	7	2	300	4	860	450	200	14,329	67.7	29,430	48,400
(Direct Current Power Consumption, Kilowatt-Hours)															
	Pneum- electric Machines	Chain Machines	Mine Pumps	Town Pump	Booster Fans	Robinson Fan	Mine Office	Stone Crusher	Cutting Props	Haulage	Total				
July.....	230	3,180	9,971	922	605	4,192	3	560	...	6,417	19,153				
August.....	202	4,138	5,681	1,219	490	4,695	3	560	230	7,454	24,670				
September.....	403	4,280	7,020	1,041	506	4,800	3	...	...	8,607	26,660				
October.....	385	7,216	7,846	896	498	4,718	5	...	...	10,056	32,620				
November.....	736	5,904	7,149	1,054	450	4,365	7	...	...	9,765	29,430				

concerning the power requirements of a mine. Fig. 17 gives the tonnage output monthly of the mine investigated through a period of five months. There is shown also the monthly kilowatt-hour consumption, the monthly cost per kilowatt-hour, the monthly cost per ton and the kilowatt-hour consumption per ton. The increased

the station. In addition, the efficiency of the station is indicated. This information is provided to correspond to the monthly statement shown in Fig. 17.

It will be observed that the average percentage of load—that is, the load factor of this station, which is a 200-kw. station—is 19.35 per cent. and that this average corresponds to the average tonnage of 12,856 tons per month.

Fig. 19 shows the ideal condition that can be obtained by using alternating current as far as possible. This figure shows the monthly consumption in kilowatt-hours of inside fans, pumps and mining machines, both on a basis of using alternating-current motors and direct-current motors. It is shown that the saving by using alternating-current motors would average 7233 kw.-hr. per month.

The foregoing is an excellent illustration of where the question is one of applying purchased power, or power from a mine power station generating alternating current. A large proportion of mines when equipping with purchased power continue all of their motor-driven apparatus on a direct-current basis. It can be readily shown, or in fact deduced from the figures used, that where alternating current is available a change-over would result in a decreased cost as incident to decreased power consumption, as well as demand, which would fully justify the change. But most important is the desirability of not loading up the substation with a load that can be more cheaply and reliably carried by stationary transformers.

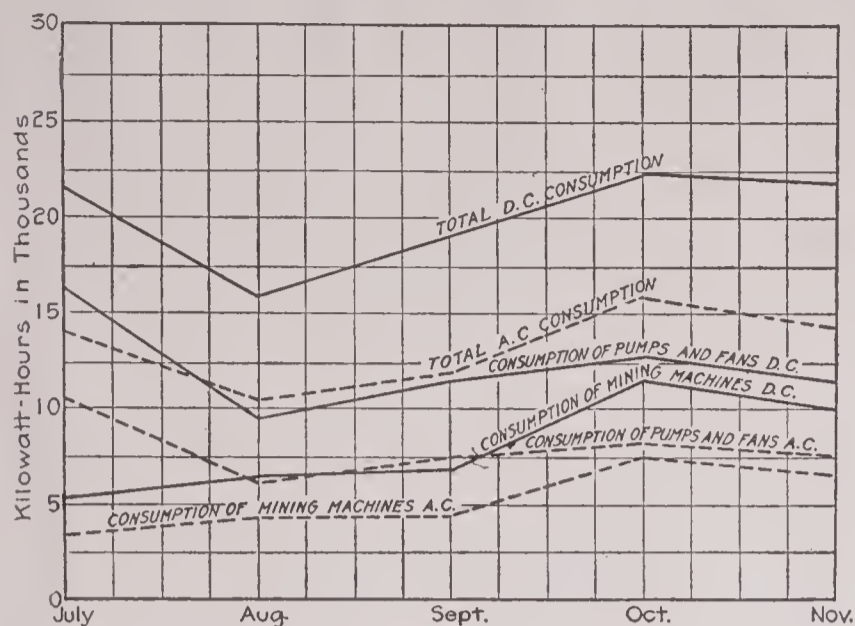


FIG. 19. THE IDEAL CONDITIONS OBTAINABLE THROUGH USE OF ALTERNATING CURRENT

or decreased cost of power corresponding to variation of production is also indicated.

Fig. 18 shows the ratio of the average power consumption to the full load capacity of the substation. It shows also the average hourly kilowatt output of

Increasing Coal Mine Efficiency—III

By CHARLES E. STUART

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SYNOPSIS—A lack of power capacity is often blamed for low voltage at the point of power application. This is seldom the root of the difficulty. Increased voltage may often be secured by connecting together various existing branches of the power line. The mechanical equipment is often in extremely bad condition, and a supposed shortage of power may be rectified by putting engines, boilers and piping in good shape. Electrified mines usually show marked superiority over unelectrified ones.

VI—Analysis of Mine Power Conditions in Relationship to Production

FIG. 20 is the resultant of a number of tests at different mines and illustrates in excellent manner the possibility of improving the voltage of the average mine by other means than through the purchase and installation of additional large quantities of copper. The improvement as indicated between curve

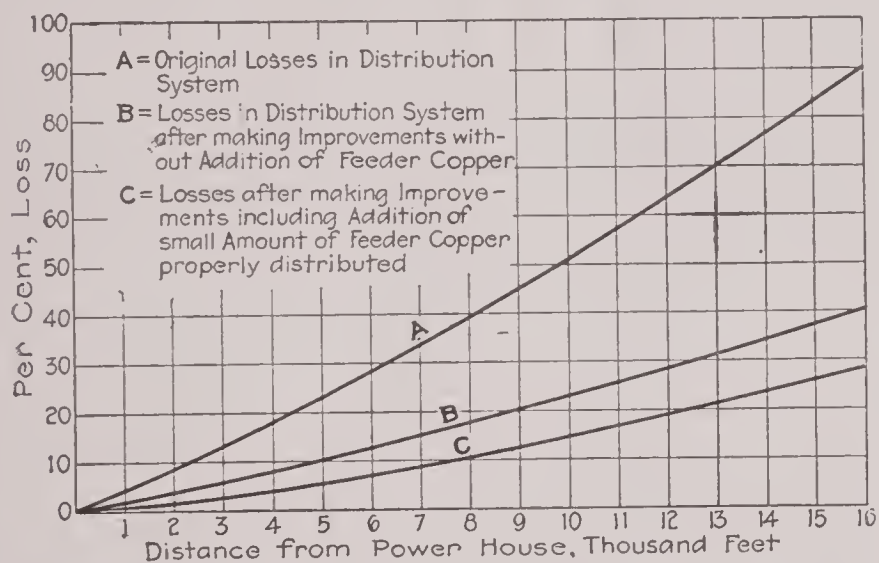


FIG. 20. THE POSSIBILITIES OF IMPROVING THE VOLTAGE WITHOUT EXCESSIVE ADDITIONS OF COPPER

A and curve B has been brought about not only by taking full advantage of all copper already placed, but in addition by improving connections of all kinds. The track bonding was perfected. In a word, conditions as represented by curve B were as nearly perfect as practicable without additional copper.

Between curve B and curve C there is represented an improvement resulting from the installation of feeder copper. A comparatively small amount of copper was necessary to obtain this improvement. That which was applied, however, was so placed as to balance the system and to place good voltage at points where conditions were most severe, rather than carry the copper transmission to those places that are seldom used.

Fig. 21 represents voltage and amperage readings on trips going in and out. The condition of the circuit is well indicated. The test deriving this information is simple and can be readily run by a capable mine

electrician with the equipment of instruments which it is criminal negligence for any mine to be without.

The proper application and distribution of copper, while not difficult, is a matter for careful consideration, analysis and test. Fig. 22 indicates the location and capacity of trolley line and feeder copper as well as electrical equipment. Analysis of this layout develops the following simple measures, of such nature as to operate the copper and rail to maximum advantage under the conditions existing.

Referring to this sketch, it would be recommended that both 4-0 wires which connect the substation with point V should be carefully connected to both trolleys going into the mine entrance—that is, both the trolley on the empty side and on the loaded side. Points J and H should be connected with a 4-0 line; S and U should be connected with a 4-0 line; D and T should be connected. The following connections should also be made: P should be connected with Q, M with N, and K with L.

In some of the foregoing instances the workings will have to progress a little farther than they are at present, but the advantage of making such connections will be readily seen; and it will be apparent that by means of these connections the utility of the copper now in use throughout the mine will be greatly increased.

As a general proposition a mine does not take full advantage of either its copper or its rail. As a result, copper that is unnecessary is frequently purchased. Conversely, the motors often operate on a lower voltage than is necessary with the copper and rail already installed.

A usual source of power and voltage loss in the average mine is at the bonds. Fig. 23 shows a group of readings taken at random. The record is a good one. The average of a well-bonded track will show a bond resistance of 8 ft. of equivalent rail, and 5 ft. is regarded as an excellent showing. Higher readings may be due to various causes, such as loose terminals and the like. Thus, in the placing of bonds the greatest care should be exercised in order to see that there is no grease or dirt either in the hole or on the bond at the time of insertion. Care should be taken that the fit be tight.

Frequently I have found only one side of the track bonded. More often there is insufficient cross-bonding and almost invariably there are loose terminals. Every fifth rail should be cross-bonded. A loose bond closely approximates a broken connection. Every mine should be equipped with a bond-testing device.

Remember always that the effects of a loose connection, a badly burned switch contact or a grounded wire cannot be overcome by increasing the generating capacity or the installation of additional feeder copper. The parallel of a bad connection is the insertion of a section of $\frac{1}{2}$ -in. pipe in a 2-in. line. Do not simply twist a wire connection, but wrap at least 20 turns with No. 10 wire and then solder well. Keep all contacts

of disconnecting switches clean. A corroded or burnt switch, or a contact that is imperfect in any way, is the equivalent of a loose connection.

Extreme low voltage is not necessarily an indication that there is insufficient copper. Such low voltage may occur in entries where the demand is of infrequent occurrence and of short duration. In such cases it would readily become a direct waste of money to attempt to build up the voltage. On the other hand, at those points where the demand is steady, as in the main entries, or where there is a steady pumping, fan or cutting machine load, the voltage should not be allowed to drop below the rated minimum for which the machines were purchased and which minimum is standard with respect to all makes of motors.

It is the rule where there is frequent armature burnout, or in fact where any class of repairs appears

an actual loss of power and corresponding wastage of fuel in a greater proportion than the actual voltage drop. Second, in a mine where, for instance, there is a 25 per cent. voltage drop, and where the station appears fully loaded, that this station is actually loaded up, not as a result of the work being done, but because, practically speaking, all over 65 per cent. of the demand represents a direct wastage of energy and a corresponding reduction of capacity. Third, bad power conditions, as stated above, mean frequent burnouts and corresponding repair cost. Fourth, there is further entailed interruption to service with corresponding reduction in output. Fifth, finally, and most important of all, is the reduction in the speed and power of the entire equipment of the mine. This may mean that four pumps are doing the work that three should do, or that four cutting machines are doing the work that should be

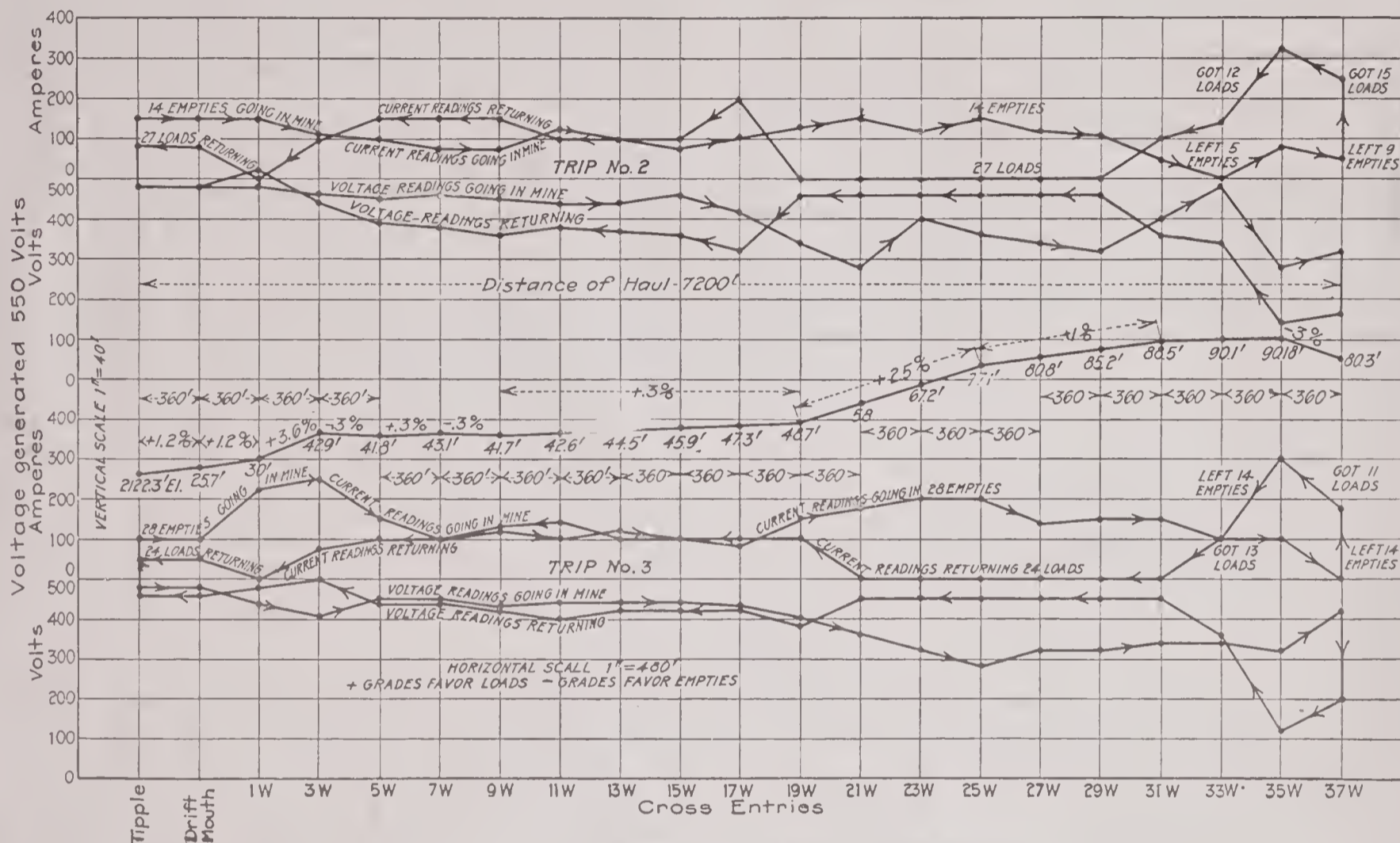


FIG. 21. VOLTAGE AND CURRENT READINGS ON MOVING TRIPS

to be too frequently necessary, to blame or disqualify the equipment. As a matter of fact, in 99 cases out of each 100 the fault does not lie here. Frequent burnout or excessive repair costs of any kind, which should stand out in a properly developed cost sheet, are an indication of neglect of equipment or of equipment operated under unfavorable conditions. If a locomotive is specified as to weight and motors for the load which it is to handle, if the power conditions are approximately those under which the locomotive is purchased to operate, and if the track conditions are reasonably good, the repair cost will rarely attract attention.

But let it be borne in mind that the actual cost of repairs represents only a small portion of the total cost. The interruptions to service, the loss of time while the repair is being made and the demoralization incident to the interruptions are the real considerations.

Bad power conditions mean the following: First,

performed by three, or that four locomotives are doing the work of three; in fact, there has often followed an even greater reduction than this in operating efficiency.

VII—Track Conditions in Relationship to Production

The trackage of a mine and the operating equipment in general may be readily compared with that of a railroad. In fact a parallel may be drawn at nearly every point. It is possible to operate the main haulage system on a rough schedule. The method of picking up cars is identical. The wrecks and interruptions to service arising from badly maintained equipment and other mismanagement that have rendered many railroads unprofitable have likewise thrown many mines into the hands of receivers and prevented other mines from making money.

The excessive grades, which in the case of a railroad cut down train length and necessitate an increase of locomotive power beyond reason, have forced identically similar burdens on the mine operator. Poor roadbeds and badly maintained trackage such as have reduced the running time of railroads and rendered their maintenance excessive, find their parallel in the mine. A well-laid track, rails of proper weight or if this is out of the question at least properly ballasted and

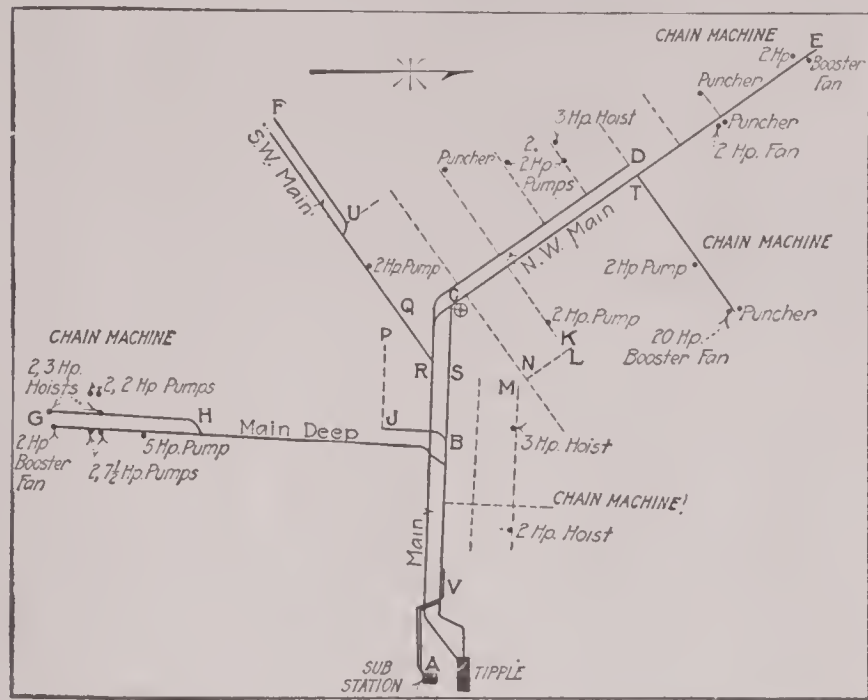


FIG. 22. DIAGRAM OF THE COPPER CONDUCTOR IN A CERTAIN MINE

properly laid, is one of the best investments that a mine owner can make.

In past years it has been the complaint that many of the old Pennsylvania, Ohio and Illinois mines could not be profitably operated on account of the long haul. The deduction is an incorrect one. There hardly exists in this country a mine where the area of development is such as would make the haulage system the determining factor with respect to economical operation.

A properly laid track kept in good repair means an increased production with a decreased cost per ton of coal mined. The reasons for this are clear; however, they may be stated as follows: There results a speeding up of the entire haulage equipment; decreased maintenance cost of locomotives and cars—bumpy track causes rapid deterioration of all rolling stock; wrecks are practically eliminated; rails not properly ballasted or maintained rapidly lose shape not only at the joints, but along the entire length.

VIII—Condition of Generating Plant

If you generate your own power, what is the condition of your engines and boilers? Will indicating engines derive such a curve as that shown in Fig. 24? I have observed and helped to make many engine tests at mines. Cards such as those shown in Fig. 24 are by no means exceptional.

I recently observed the investigation of a power plant of a mine which in most respects is well operated. Seven 150-hp. boilers were feeding three 200-kw. engine-driven generating sets. Using a high-grade fuel five firemen were having a hard time maintaining 60 lb. of steam pressure. The operator in question proposed

to purchase additional boilers and generating equipment. Acting on the advice of an engineer, he decided not to purchase this equipment but to rebores the engines and reset the valves, cover the steam piping and install a feedwater heater. The scale was removed from the boilers, the tubes thoroughly cleaned and the settings repaired. As a result, four of the boilers and two of the generating sets carried the load readily.

This example may appear extreme; but if the manager of the average operation really thinks it is, let him conduct a test at his own plant. There is no great expense attached to such a trial, and I believe that the results in many instances will be amazing.

IX—Relative Output of Electrified versus Unelectrified Mines

Table V makes a direct comparison between two mines operating in the same coal bed, the one electrically equipped and the other hand-worked. The table shows that the average number of tons produced per day by each man is 3.94 in one case and 2.64 in the other.

	Electrified Unelectrified		Increase Output Electrified Mine Over Unelectrified	
	8 ft.	8 ft.	Amount	Per Cent.
Thickness of seam.....	8 ft.	8 ft.		
Kind of opening.....	Shaft	Slope		
Method of mining.....	Machine	Pick		
Kind of machines.....	Electric	None		
Method of haulage.....	Mechanical	Mules		
Men employed, total.....	402	550		
Miners.....	234	305		
Inside men.....	108	120		
Outside men.....	60	125		
Yearly output in tons.....	485,806	450,389		
Output per miner.....	2,092	1,476	616	42
Output per man, total.....	1,218	819	399	48
Number of days operating.....	308	310		
Number of tons per man per day (total).....	3.94	2.64	1.30	50
Number of tons per miner per day.....	6.79	4.7	2.09	45
Kind of haulage.....	{ Electric Locomotive			

Thus, there is shown a clear gain of 1.3 tons, or 49 per cent., each day by each man in the electrically equipped mine.

Considering the state in which these two mines are located and giving due consideration to the characteristics of the different seams operated, it is estimated that if all the mines now hand-worked were to be

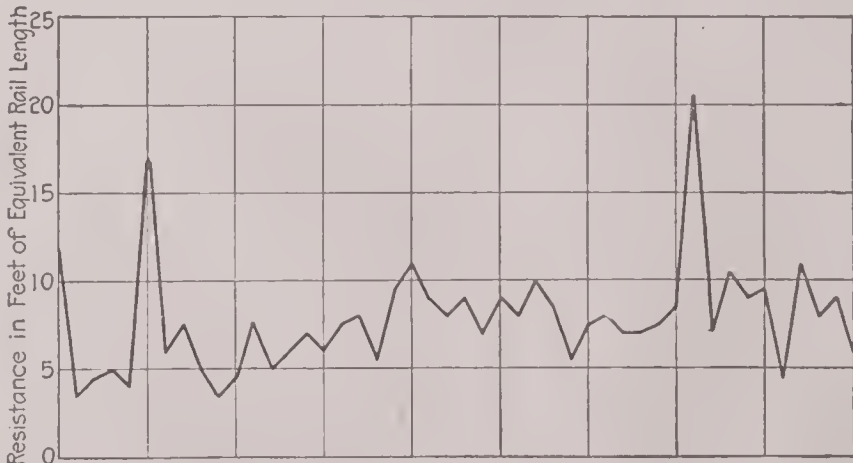


FIG. 23. RANDOM READINGS ON RAIL BONDS

electrically operated, there would be an increase in output of over five million tons; that is to say, the output of the state would be increased by over 25 per cent.

To obtain this increase in output there would be necessary an expenditure of about four million dollars, or approximately 75c. for each ton of increased yearly production. This sum of money in its relationship to the value of the increased production and as measured by the increased requirements of machinery is relatively

small when compared with the cost incident to coal conservation measures which are under way in many sections of the country.

Table VI shows the cost of cutting coal at a certain operation and the estimated cost assuming that electrical equipment were installed. Data gathered since a partial electrification has taken place fully bear out the figures shown. The table is introduced to show the magnitude of the saving made possible through the application of the electric drive.

This table shows that a saving of from 15 to 20c. on each ton produced should be possible when the operation

is completely electrified. In the state where this operation is located, assuming a saving of 15c. per ton, and with a total production from unelectrified mines of 11,000,999 tons, the figure of approximately one year ago, there would accrue a saving in the cost of production in the period of one year of \$1,770,000.

These figures, as stated, represent an analysis made

TABLE VI. VARIOUS ITEMS IN PRODUCING COAL UNDER PRESENT UNELECTRIFIED AND UNDER PROPOSED ELECTRIFIED CONDITIONS

Cost of Cutting Coal		Present	Proposed
Labor.....		17.00c.	5.70c.
Power.....		4.93	1.12
Total.....		21.93c.	6.82c.
Cost of Haulage			
Rope.....		0.25c. labor	3.30
Mule.....		8.00 power	1.40
Gas engine.....		1.70 hoist	0.20
Total.....		9.95c.	11.72c.
Cost of ventilation.....		0.49	0.63
Cost of dewatering.....		0.10	0.08
Cost of screening.....		0.19	0.17
Cost of washing.....		0.58	0.27
Total.....		33.24c.	12.87c.
Cost of Pumping			
River pump.....		0.63	0.39
Cost of operating gin engine larry and tabby.....		0.23	0.32
(Not total, but cost affected by change in power).....		34.10c	13.58c.
Saving.....			20.52c.

in one state. There is, of course, considerable variation in costs in this state and with respect to the different coal beds operated. Relatively, however, the estimates both as to increased production and decreased cost will hold true as between the different beds. They are also valuable when considering operating conditions in other states.

The mines that remain unelectrified are numerous. In the majority of operations, however, competition has forced electrification, even where decreased cost and increased production have not proved a sufficient incentive. The position of the partially electrified mine can be deduced to some extent from the facts given.

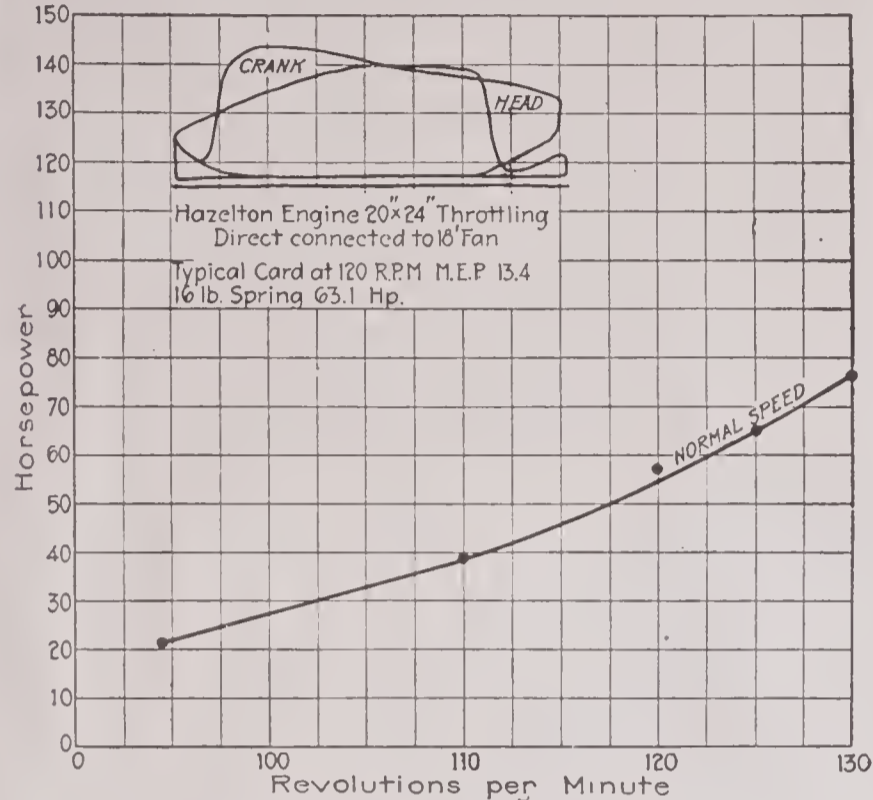


FIG. 24. A NOT EXCEPTIONAL INDICATOR CARD AND POWER CURVE

Increasing Coal Mine Efficiency—IV

By CHARLES E. STUART

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SYNOPSIS—*This article is devoted to the efficient electrification of a coal mine using purchased power. In many cases, aside from securing current at a less cost per unit than that for which it can be generated, purchasing current has the advantage of putting its cost visibly on the cost sheet. Care exercised in changing over from one source of energy to the other is care well spent, as many economies can usually be made.*

WHILE central station power is not available at the present time in many coal fields except through increasing the demands on stations already connected up, there are other coal fields where there is a considerable surplus of capacity. In either case I believe that the following description will be of some value. It may offer suggestions to mines now fairly well equipped. It should certainly prove timely to operations that are increasing their equipment or electrifying new developments.

Considerably over half of the coal produced today is mined with the aid of purchased power. Take the Pocahontas fields of West Virginia, for example. The Appalachian Power Co. began to cover this field with its transmission system in 1911. Today half of the coal of the field is mined with power from this source; another 20 per cent. is mined with power generated in the central station of the United States Coal and Coke Co.



FIG. 25. TYPE OF TRANSFORMER STRUCTURE EMPLOYED

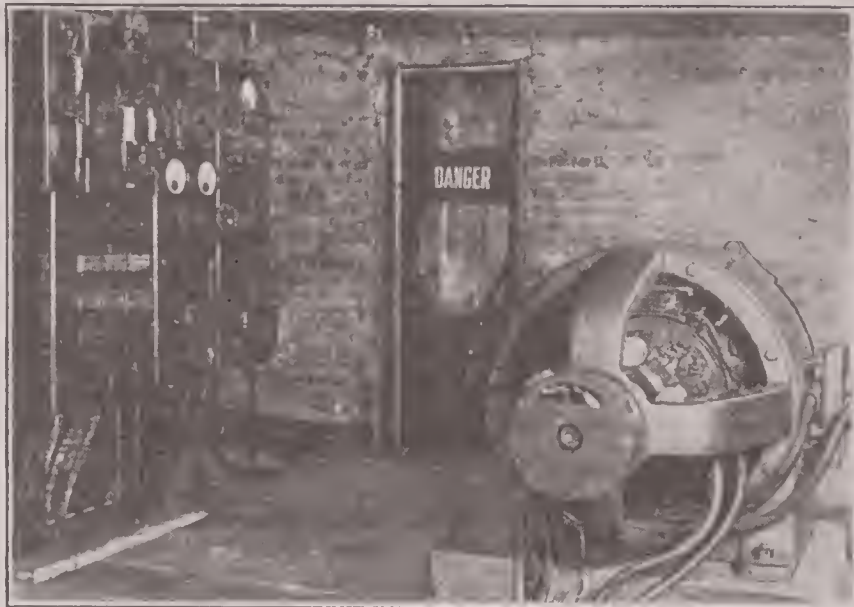


FIG. 26. ROTARY CONVERTER IN UNDERGROUND SUBSTATION

The remaining 30 per cent. is mined with the aid of isolated plants, nearly all of which were installed prior to the development of the system of the Appalachian Power Company.

The considerations in favor of purchased as against manufactured power may be briefly stated as follows: The elimination of the supervision necessary to properly operate and maintain a power station; elimination of skilled and semi-skilled labor, such as engineers and firemen, and the conservation of fuel attendant upon purchased power. A series of tests in the Pocahontas coal field (and these tests represent a pretty fair average) show that 11.6 lb. of coal are consumed for each kilowatt-hour generated. A central station making power in that field will operate at about $2\frac{1}{2}$ lb. of coal per kilowatt-hour. A saving of approximately 9 lb. of coal for each kilowatt-hour used, or an average of 9.1 lb. of coal for each ton mined is thus possible.

In the anthracite fields of Pennsylvania, the estimate of coal consumed per kilowatt-hour is 16 to 17 lb. In this case, and for the purpose of the estimate, steam used for fan drive, pumps, etc., has been converted into the electrical unit. In fact, it is estimated in the anthracite field that a production of 90,000,000 tons of coal represents at least 9,000,000 tons of coal burned to produce power for this tonnage output. Central station electrification of this field would mean a saving of approximately 8,000,000 tons as now required in the production of energy for mining.

A summary of comparison made in the Pocahontas coal field shows 3 kw.-hr. consumed per ton of coal produced for purchased power and 5.8 kw.-hr. consumption per ton for manufactured power. This saving is the result of the elimination of line losses through placing the converting stations at the load center, by utilizing two-speed fan motors and by the practice of economy which invariably follows where the direct relationship between power consumption and monthly cost can be observed.

With purchased power it is possible to use alternating current motors for nearly all stationary-motor

work. These motors are extremely reliable, and they require little or no attention except occasional oiling of the bearings. They represent the ideal stationary motor for the mine, being as nearly foolproof in construction as it is possible to build. As a rule purchased power is less costly than manufactured power. This, however, is not always the case. There are numerous varying factors governing this consideration.

Before going into a description of a specific installation it should be stated that it was the intention of the mine owner, the engineer and of the power company to spare no reasonable expense in order to make this installation efficient. I will first give a general description of the layout of the plant before purchasing power, and then show just what methods were adopted for the use of purchased energy.

The main power plant consisted of two 150-kw., 275-volt, direct-current General Electric generators direct connected to Harrisburg slide valve engines. From the main power plant distributing lines were run out at 250 volts direct current, to supply the mine, fan, tippie, pumps, shops, lights and miscellaneous power used. The greatest distance from the power plant to the back of the lease was approximately 3 miles. This necessitated the use of heavy copper extending into the mine $2\frac{1}{2}$ miles. Even then the voltage on the 250-volt circuit well back in the mine was as low as 150 volts with heavy pulling.

The fan was located at the drift mouth, 1500 yd. from the main power plant and was supplied over a 2/0 circuit. The voltage delivered at the fan motor was as low as 200 when the load was pulling heavy. The fan was driven by a 75-kw. Westinghouse direct-current generator running as a motor.

The tippie was driven by ten motors aggregating 335 hp., varying in size from 75 hp. to $7\frac{1}{2}$ hp. and controlled from three different points on different landings. As all of this apparatus was operated by one man it was necessary for him to go from place to place in starting up the tippie and to climb up and down many steps. All wiring was of the open type run on knobs and through tubes, while in many cases it lay on steel girders. Tests were made on each motor separately in order to see if any power demand could be eliminated. While these tests showed that in several cases machines were over-horsepowered, still it was deemed advisable on account of the cold weather conditions not to change



FIG. 27. TRANSFORMERS EMPLOYED UNDERGROUND



FIG. 28. METHOD OF SUSPENDING ELECTRIC LINE IN THE AIR COURSE

any of the sizes of the motors. The lowest potential recorded during this test was 200 volts. The tippie was fed by two 4/0 circuits.

The deep well pump was driven by a 10-hp., 250-volt, direct-current motor and was supplied from the circuit feeding the tippie, being about 100 ft. therefrom. The speed of this motor was varied by means of resistance, and in this way it was possible to pump just enough water to meet the requirements, without continually overflowing the tanks.

The machine shop was driven by a 10-hp., 250-volt, direct-current motor driving line shafting from which the various machines such as air compressor, lathe, drill press, boring machine and the like, were driven.

The lights were fed from a three-wire circuit, controlled by three single-pole knife switches, using the middle wire as a common return for the two outside wires, and maintaining a day and night circuit. Thus, by pulling one of the outside switches, the night circuit could be killed, or, vice versa, the day circuit could be switched on. All miscellaneous power such as refrigerator, motor for store, general manager's house, meat choppers, etc., were supplied from the day circuit.

NEW EQUIPMENT FOR PURCHASED POWER

I will now give a brief description of the general layout adopted. As shown at the beginning, the losses were considerable by the time the current reached to the most remote point in the mine from the main power plant. In order to keep the losses at a minimum, it was decided that two substations should be installed, one in the existing power plant and one inside the mine. A description of each is given separately under "Outside Substation" and "Inside Substation," later on in this article. In order to meet the situation most effectively it was decided to adopt two different voltages—that is, to install two banks of transformers. The type of transformer structures used is shown in Fig. 25. In describing the transformer stations I will designate them as bank No. 1 and bank No. 2.

Bank No. 1 consists of three, 100-kv.-a. 13,200/440-volt transformers located approximately 50 ft. from the tippie. From the secondary buses of these transformers a three-phase, 440-volt line runs to a main feeder panel in the tippie, and three of the two-circuit 4/0 feeder wires leading from the main power plant to the tippie were converted into a three-phase, 440-volt circuit leading to the outside substation located in the main power plant. The current is measured on the secondary side of the transformers, the coal company having a check

meter installed, as well as a meter on tipple circuit and pump, outside substation and lights and shop, thereby giving a correct proportion of the power chargeable to each installation.

Bank No. 2 consists of three 75 kv.-a., 13,200/2300-volt transformers located at the drift mouth. From the secondary buses of these transformers a 2300-volt, three-phase line runs into the fanhouse, tapping a three-phase bus, from which a circuit is fed through 2300-volt disconnecting switches to the fan and through 2300-volt disconnecting switches and a 2300-volt time-limit, overload, no-voltage release oil switch to the line running to the inside substation. The current is measured from buses in the fanhouse, the coal company having a check meter, as well as a meter on the fan circuit.

Outside Substation—The outside substation consists of a 150-kw., 250-volt, direct-current, six-phase, 1200-r.p.m., Westinghouse rotary converter with three single-phase transformers from 440 to rotary voltage, and a switchboard containing all necessary starting and control apparatus, also one automatic reclosing direct-current circuit breaker, thereby eliminating a constant attendant in the substation. In addition to the direct-current feeder for the mine circuit, there is a separate direct-current feeder for the larry circuit and boom hoist located in the tipple and controlled through circuit breakers and single-pole knife switches. A direct-current meter was installed on the larry circuit showing the kilowatt-hour consumption of the larry.

DESCRIPTION OF INSIDE SUBSTATION

Inside Substation—Before describing the electrical apparatus for the inside substation, I should like to give a brief description of the location and character of the room built to house the necessary apparatus. After having selected the space for this substation, which was in a breakthrough between air course and main entry, it was necessary to remove a considerable amount of coal and slate in order to get sufficient space for the installation.

The apparatus is installed with a view to being able to move any part without interfering with any other. For instance, it is possible to move the rotary, switchboard or any of the transformers without conflicting with either of the other two. The walls are built of brick, being as thick as the width of a brick on the side walls and the length of a brick on end walls. Next to the main entry a double door of sufficient size was installed to enable removal or replacement of any of the apparatus, and a single door opens into the breakthrough leading into the air course. By means of ventilators located in both doors, it is possible to regulate the amount of air flowing, and in this way the substation is kept cool at all times. From the roof the slate was taken down as far as the sandstone top, and left in this condition. This has thus far given satisfaction, and from all appearances will continue to do so.

The apparatus for this substation consists of a 150-kw., 250-volt, direct-current, six-phase, 1200-r.p.m., General Electric rotary converter, with three single-phase transformers stepping the voltage down from 2300 to rotary voltage, and a switchboard containing all necessary starting and control apparatus, also one automatic reclosing direct-current circuit breaker. The inside substation apparatus is shown in Figs. 26 and 27.

When it was decided to install this substation in the mine, estimates were made in order to ascertain if it would be more feasible to put a borehole down through the mountain or run a line through the air course. It was finally decided to adopt the latter. Accordingly a three-phase, 2300-volt line was constructed and run through the air course. The type of construction is shown in Fig. 28. Some anxiety was felt as to how this line would hold up on account of slate falls, but a careful inspection of the air course was made and all loose slate or any that was thought likely to fall was taken down.

This line has been in operation now practically a year and there have been only two interruptions; and these were not of a serious nature. The oil switch located in the fanhouse kicked out, but when closed again the line showed clear. It is therefore believed that small pieces of slate fell, causing a momentary short-circuit. The

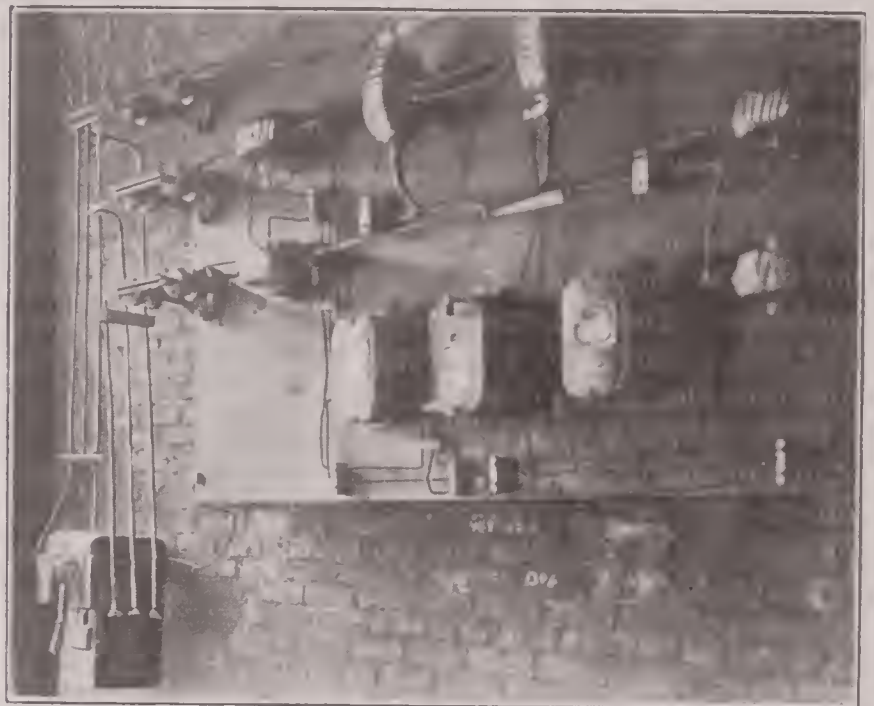


FIG. 29. OIL AND DISCONNECTING SWITCHES IN THE FAN HOUSE

oil switch located in the fanhouse, with disconnecting switches and other apparatus, is shown in Fig. 29.

In place of the 75-kw. generator operating the fan a 100-hp., two-speed, 2300-volt Allis-Chalmers induction motor was installed together with a starting compensator, pole-changing switch, and two sets of overload and no voltage releases, these being of the two-coil type, one to operate on high speed and one to operate on low speed, thereby guaranteeing safety from overloads on both operations. As stated before, there is a separate meter on the fan circuit showing the exact kilowatt-hours chargeable to ventilation.

Special attention is called to the method of control adopted for the tipple. This is shown in Fig. 30. The operator, a one-armed man, has all of his control apparatus located at one central point and arranged so that he can start each machine in its proper order. All wires for the tipple motors were figured and installed of sufficient capacity so that the total drop from the secondary buses of the transformers to the motor would not exceed 5 per cent. All wiring was run in conduit with proper condulets installed on each outlet. Practically all motors were of the slip-ring type, thereby taking care of the heavy starting load, which was a source of nuisance with the direct-current motors, especially in cold weather.

A 10-hp., 440-volt, two-speed induction motor was installed to handle the pump load, thereby enabling a two-speed operation in order to meet the condition, as desired, for this service. A separate meter was installed on this circuit in order to obtain the amount of power chargeable to water supply. A 10-hp., 440-volt induction motor was installed in the shop, driving line shafting to which all operating machines were connected.

The three-wire, 250-volt, direct-current circuit was converted into a three-phase, 440-volt circuit, the two outside legs of this circuit being controlled through circuit breakers and the middle leg through a single-pole knife switch. From this three-phase circuit leading out of the substation 440/110-volt transformers were installed to take care of the lighting and miscellaneous power. These transformers were so located that no secondary lines from the transformers would exceed 500 ft. in length using No. 8 wire for secondaries. There are two single-phase meters installed back of the switchboard on the three-phase, 440-volt circuit for measuring the kilowatt-hours chargeable to lights and miscellaneous power.

The accompanying figures for purchased power are based on actual records up to June of 1918. The figures for manufactured power are based on 1914 records, allowing for the increase of costs, as incident to present conditions. These figures show a reduction in power cost; also, a reduction in kilowatt-hours consumed. The mine fan, due to the delay in arrival of certain control parts, has never been operated at half speed.

Certain special considerations incident to the application of purchased power arise and require determination. Among these is the question of selection of motor-generator set or rotary converter. Within the last five or six years the 60-cycle rotary converter has been brought to a state of construction perfection where it is one of the most satisfactory and reliable pieces of

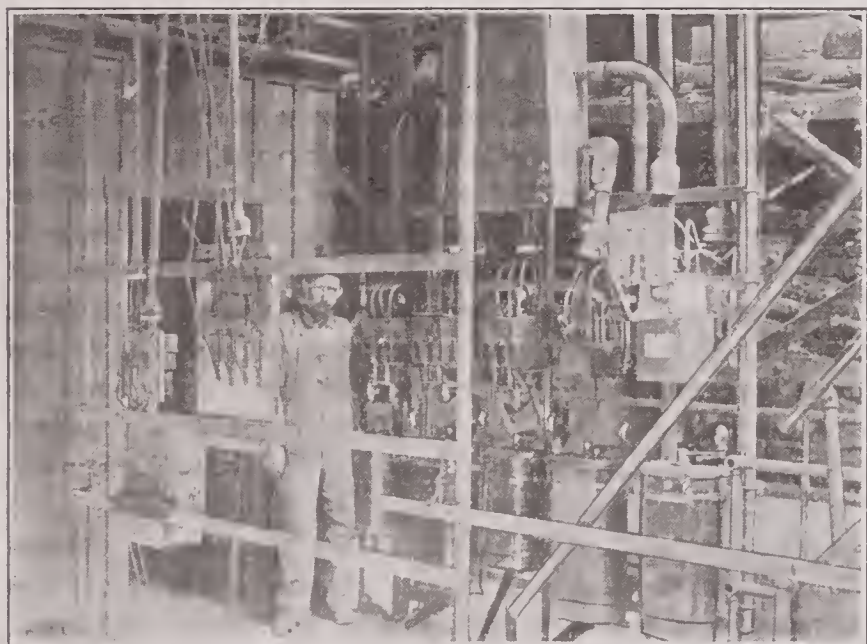


FIG. 30. GROUPED CONTROL APPARATUS IN THE TIPPLE

conversion equipment that can be obtained. This is true whether the case in question is one of operating a single-unit substation, the parallel operation of units in the same substation, or of parallel operation of two or more substations located at different points.

The rotary converter will carry a remarkably heavy overload without flashing. In fact it will readily carry from 100 to 200 per cent. overload on peaks of short duration such as are characteristic of the mine load.

Moreover, the operating efficiency is much greater than that of the motor-generator set. Difference in efficiency becomes more pronounced when considered with respect to the low load factor which is characteristic of the mine load. Fig. 31 is designed to compare the efficiency of a 200-kw. motor-generator set with that of a 200-kw. rotary and of a 150-kw. rotary. This particular com-

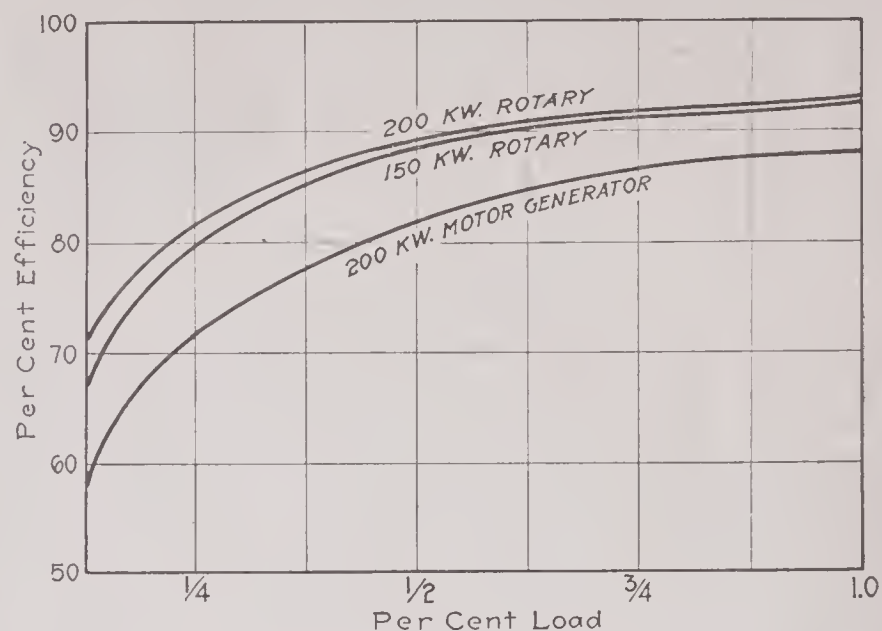


FIG. 31. COMPARATIVE EFFICIENCIES OF TWO ROTARIES AND MOTOR GENERATOR

parison was made for a mine which was using a motor-generator set, but increasing its substation capacity.

Based on the monthly output of the motor-generator set over a period of five months, it was determined that by the installation of a rotary converter and assuming a power cost of 1c. per kw.-hr., the 200-kw. rotary, if substituted, would save \$628 per year. The changeover was made in the case referred to, although the motor-generator set had at the time been in opera-

MANUFACTURED POWER (COST)

Power Consumption, 859,209 Kw.-Hr.	Tons Mined, 215,457
Coal 2761 tons @ \$2.40.....	\$6,526.40
Engine repairs.....	807.00
Generator repairs.....	36.34
Boiler repairs.....	530.00
Sundry tools.....	79.74
Supplies from store.....	58.10
Cost for ash disposal.....	109.32
Fire insurance and workmen's compensation.....	420.20
Firemen and engineers.....	5,047.00
Repairs—labor.....	518.29

Total.....	\$14,457.39
Superintendence.....	2,000.00
Depreciation.....	844.12

Total.....	\$17,301.51
Cost per kw.-hr.....	\$0.02013
Kw.-hr. per ton mined.....	.4
Cost per ton mined.....	\$0.08052

PURCHASED POWER (COST)

Tons mined.....	233,460
Purchased power (822,660 kw.-hr.).....	\$9,876.00
Repairs to substations.....	196.56
Supplies from store.....	19.92
Substation attendant.....	282.00
Fire insurance and workmen's compensation.....	125.28
Superintendence.....	2,160.00
Depreciation.....	844.08

Total.....	\$13,503.84
Cost per kw.-hr.....	\$0.01641
Kw.-hr. per ton mined.....	2.84
Cost per ton mined.....	\$0.05660

tion through a period of about two years only. The results have been as anticipated.

Rotaries of the same rating as the motor-generator sets replaced have shown themselves to be of relatively greater capacity. Likewise they have shown equally as great reliability in service. I do not recommend the rotary under all circumstances; however, where the system from which the supply of power is obtained is a modern one, there is little or no exception.

Increasing Coal Mine Efficiency—V

BY CHARLES E. STUART

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SYNOPSIS—*This, the last article of the series on this subject, deals with central station conditions and problems. Many such stations are overloaded during the day, and as additional equipment is difficult to obtain these stations and their war-industry customers are faced with some objectionable but not altogether destructive alternatives.*

IN MANY mine centers served by central stations, as well as in other war-industry centers such as the Pittsburgh and Philadelphia districts, there is a growing power shortage and in other sections an approaching shortage. This fact is due to the rapidly increasing demand incident to the speeding up of industry to meet war necessity. I am familiar with a case where the demand on a central station serving coal mines almost exclusively has doubled within the period of a year.

Fig. 32 is a load curve of one of the largest central stations in the country serving mines. It will be observed that the demand is actually in excess of the present capacity of the generating station. In this particular case the present condition is the result of breakdowns. At the same time the company in question has insufficient reserve capacity and for that reason the failure of one of its larger units is sufficient to curtail service to the entire system.

ADDITIONAL UNITS MEAN INCREASED INVESTMENT

The question will be asked: Why not increase the generating capacity by additional units? To do this, as a rule, involves heavy investment cost. Many of the utility companies under present operating conditions cannot show a balance that would enable them to finance such an investment. Moreover, where satisfactory earnings are shown, there arises the question incident to the present high cost of apparatus and the relationship of such excessive cost to the conditions that will exist after the war, and particularly when the load falls off.

But even where the financial condition of a company is favorable, as is true in cases, there is involved the impossibility of financing against Government requirements and the difficulty of financing under the rules of the War Finance Corporation.

In spite of these considerations, the central stations are obtaining a great deal of financial assistance where it is necessary. However, even with funds needed for improvement in hand, equipment must be obtained and installed under nearly impossible conditions. There is a demand for turbine equipment far in excess of the supply. A turbine of any size today cannot be obtained within a year. Boiler manufacturers are in the same condition as are the turbine builders.

Where a breakdown occurs there is delay in effecting repairs, even with all the priority assistance that can be given. Furthermore, there is the consideration of

skilled labor necessary to look after the complicated requirements of a central station system. Linemen and other similar help are not exempted. The chief engineer or the chief dispatcher in the central station is liable to call on short notice, with attending demoralization to service. All of these facts are focusing the consideration of the mine owners and central station operators toward establishment of measures of relief.

MINE POWER SERVICE RECEIVES PRIORITY

In Pittsburgh and Philadelphia recently the office hours of buildings, department stores, lofts and other similar power users have been staggered. No lighting or elevator service, for instance, is allowed to meet such requirements between 7:30 a. m. and 10 a. m. Mine power service in the Pittsburgh district has been given priority over service to all other war industries; thus, the steel mills in the Pittsburgh district are being subjected to shutdowns, while the coal mines are kept running. Non-war loads, such, for instance, as the glass manufacturers, have been required to go on night shift. Certain war loads are doing the same. The steel mills are already operating a night shift.

There are a number of alternatives with which the coal operators, as well as the central stations serving mines, will be faced, as conditions grow more acute. Some of these are enumerated as follows: Placing all non-war loads on night shift, insofar as they conflict with the mining or other war-industry loads. Placing cutting machines and pumps on night shift, where this particular class of load, if so placed, would take sufficient demand from the day load to be of assistance. This is now being done in the West Virginia fields. To stagger the loads—that is to say, start certain mines at an early hour in the morning, other mines a few hours later, and so on, thus flattening out the peak, and where conditions are extreme, to operate groups of mines on alternate days. The advantages from such procedure would be that the mines in operation would have continuous service and would not be subject to frequent shutdowns throughout the day, which has been found to be far more disastrous to the output than the alternative suggested.

STAGGERED SYSTEM IN WEST VIRGINIA

The precedent for these suggestions was the arrangement made in the West Virginia coal fields a few months ago when a large unit broke down. In that case certain mines were operated in the morning and other mines in the afternoon.

The West Penn Power Co., of Pittsburgh, is suffering at the present time through a lack of capacity. In this case all non-war load has been thrown on night service. Even so, however, the demand is still in excess of the capacity by about 10 per cent. It has been arranged to cut off certain circuits for a period not exceeding 10 minutes and to rotate the cutoff so as to include all of the mines during the day. Thus, any one mine is liable to cutoff from one to three times per day for a period

of 10 minutes at each cutoff, or a total of 30 minutes during the day.

The result of the foregoing is to more or less systematize interruptions. The mines know when an interruption occurs that it is not going to last for more than 10 minutes. It is not possible to give any previous notice of an interruption, since the circuits are only taken off as the demand on the power plant exceeds a certain capacity, and that demand can never be predicted in advance. In this connection it has been found necessary to arrange for better coöperation between the telephone company, the central station and the mine, so that information concerning interruptions can be quickly transmitted.

There remains the radical alternative of night operation of mines. At the present time the West Penn Power Co. is taking on no new contracts unless the min-

There are, however, on account of established precedent in this country, many difficulties to be overcome, and it is with a full knowledge of these difficulties, both physical and psychological, that I suggest that night operation may become inevitable in certain centers.

Not to do an injustice, it may be observed that many of the central stations serving mines have today ample capacity for their present as well as for additional load. Moreover, it is difficult to say that an operator with his own plant, the demand upon which is increasing, is in a particularly favorable position. The difficulty of expanding individual installations or of making new ones involve the same element of time, and the same considerations of high cost and skilled labor as those pertaining to central stations.

Today it will be far simpler from all angles to meet any large demand for additional power by increasing

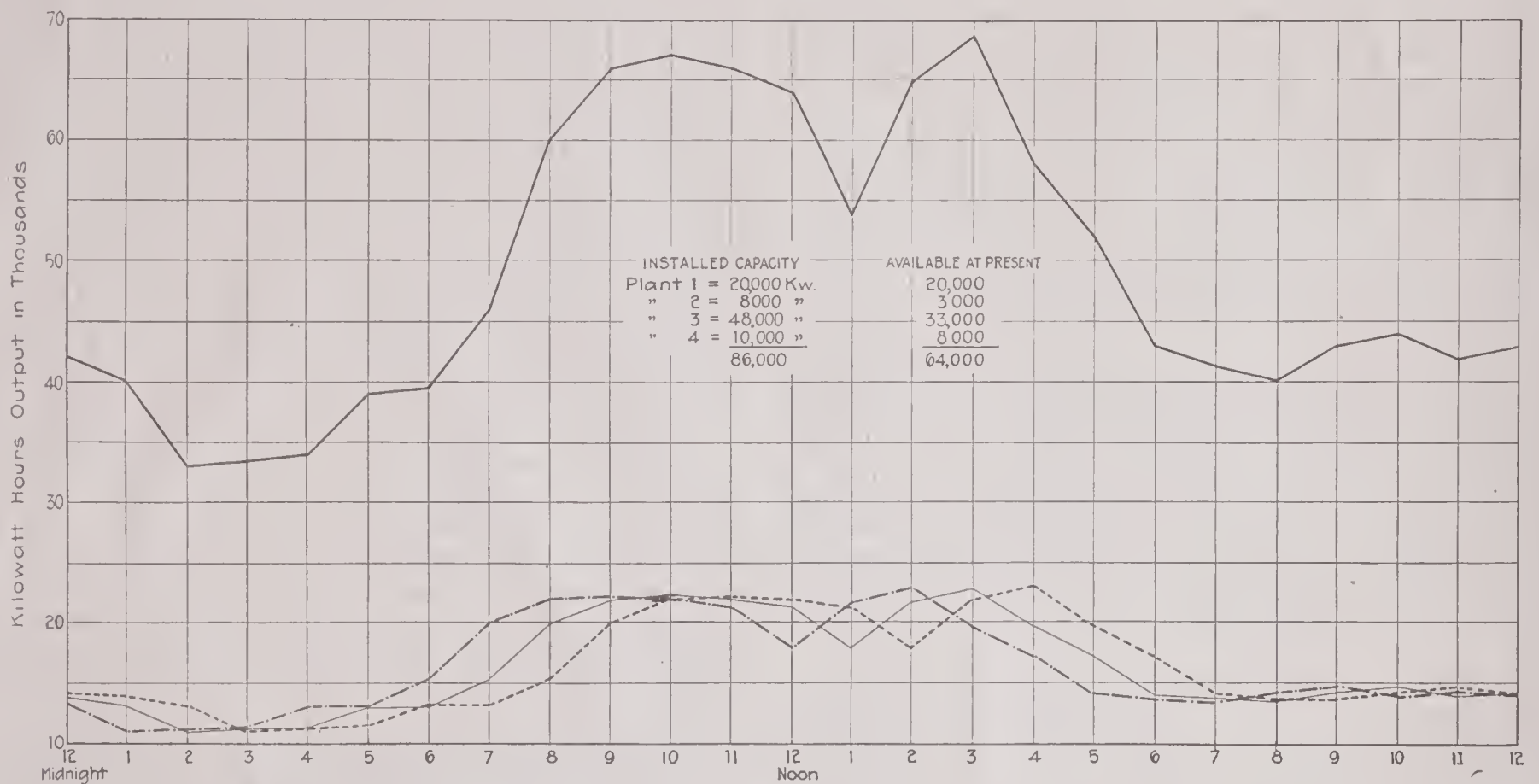


FIG. 32. LOAD CURVE OF A LARGE CENTRAL STATION COMPANY

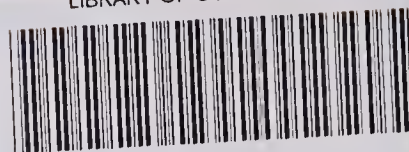
ing company is willing to operate at night. By referring to Fig. 32 it will be seen that after four o'clock in the afternoon and before seven in the morning the load curve is far within the generating capacity. Between these hours it is possible to take on additional load.

A few mines have accepted the alternative of operating at night, but they have not been on this service long enough to report results. However, it can be readily seen that the adoption of such an alternative may become inevitable, if production is to be maintained. Though the suggestion where made has been received with considerable disapproval, it may be noted that already many classes of war industries are accepting the inconvenience attendant upon night operation.

It is difficult to see why, if the steel mills, for instance, in normal times can satisfactorily operate on night shift, the mines cannot do the same, provided the necessity is sufficiently urgent. England, France and Germany in peace times have all established the precedent of a night shift. In a number of the mining centers of this country cutting machines and pumps have always been operated at night.

central station capacity than by the expansion of isolated plants, or the building of new isolated stations. Finally, it should be observed that through following some of the prescriptions elsewhere indicated, the operator himself can go a long way toward assisting the central station to take care of its load.

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